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THE NEOCENE DEPOSITS OF KERN RIVER, CALIFORNIA, AND THE TEMBLOR BASIN

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Preface

The first visit of the writer to the Kern River district was made in the spring of 1902; and the stratigraphic observations begun at that time have been extended from time to time each year as opportunity offered, until the summer of 1910. While this work was not begun nor carried on with the intention of publishing any of the results, yet the study has proved so interesting, and the results are in some respects so different from what had been anticipated after a considerable study of the Neocene deposits along the California coast, that it appears worth while to present some of the more general facts in the following paper.

One of the interesting points brought out by this study is the suggestion of a rather provincial character in the Neocene stratigraphy of the coast, which had been assumed to be uniform, at least within the limits of a single unit basin. It would be carrying the subject too far at the present time to attempt a close correlation of these Kern River deposits with any beyond the limits of their basin, but an attempt is made to point out the limits of the area within which such a correlation may properly be undertaken. The name used for this physiographic unit, the *Temblor Basin,* is the name used also for the more widely distributed and characteristic strata of the Neocene, that is the Lower Miocene, or Temblor Beds. There are other good reasons that may be brought out later for the adoption of this name, but for the present this one is perhaps sufficient.

The fossils and other material which had been collected from this region prior to 1906, had been largely donated to the California Academy of Sciences, and were lost in the great fire. Since then the Academy has made explorations in this field, and as a result has not only restored its collections, but has added considerably to our knowledge of the Kern River region. It is due to acknowledge in this connection the part taken in this work by Mr. W. H. Ochsner, Mr. A. G. Carpenter, and Mr. John P. Buwalda. Mr. Carpenter lived for several years at the electrical power-plant station situated on Kern River at the contact of the granite and the Neocene sediments.

He has made extensive and interesting collections in the Temblor beds at the base of the Neocene, and has made important donations of fossils to the California Academy of Sciences.

Mr. Ochsner and Mr. Buwalda each spent a considerable time studying the stratigraphy of the field, and making collections, the results of which have all been turned over to the Academy.

The identification of the fossil plants obtained from this field, in so far as identification has been secured, was made by Dr. Willis L. Jepson of the University of California.

It is proper also to mention in this connection the generous and co-operative attitude of Professor E. T. Dumble, Consulting Geologist of the Southern Pacific Company.

And lastly, the friendly interest taken in this work throughout by Dr. J. Perrin Smith, Dr. John C. Merriam, and Dr. Andrew C. Lawson, has been encouraging and gratifying in a high degree.

General Statement

One of the most striking features of the geology of the Great Valley of California is the relative lack of Cretaceous and Tertiary strata on its eastern border. Considering its synclinal structure, and the great display of strata along its western border, which range through all the periods from Cretaceous to Pleistocene, it is remarkable that there are so few occurrences of similar formations along the foot-hills of the Sierra Nevada. Certainly the streams coming into the valley, or basin, from the east during these successive periods must have contributed greatly to contemporaneous deposits; or rather, the quantity of detritus entering from the east could not have been small, and, under the assumed conditions of grade, would presumably be commensurate with the time-duration and the areas denuded. Naturally, therefore, larger collections of strata would be expected on the eastern than on the western border of the valley, and their absence is all the more surprising.

If thick deposits of strata were ever formed along the eastern border, but little evidence of them is visible. The basement rocks of pre-Cretaceous age usually come well down

to the present valley floor, and the few occurrences of later strata are in detached areas of only local extent. One of the most important of these areas is in the vicinity of the Kern River and its neighboring streams. Between White River and the Tejon valley for a distance of 50 miles there is a zone of low hills three to fifteen miles wide, occupying a position intermediate between the Sierra Nevada and the Great Valley. This zone of low hills consists almost entirely of Neocene strata resting in a gently inclined position against the granitic and metamorphic rocks of westerly Sierran spurs. In general the area is lenticular in outline, its widest part being in the vicinity of Poso Creek and the Kern River. The stratigraphic and faunal features of this area are the chief subject of the following paper, though it naturally embraces many related topics.

Review of Literature

Although the Tertiary strata in the vicinity of the Kern River were among the earliest in California to receive notice from geologists, and their fauna has long been believed to be exceptionally rich, yet comparatively little has been done to gather from this quarter the material they might furnish toward the development of our knowledge. At the close of this paper will be found a brief bibliography of the more important papers in which this area has been at least mentioned.

In 1853 a party of U. S. topographical engineers under the leadership of Lieut. R. S. Williamson, with Wm. P. Blake[1] as geologist, visited this region and made a camp for some weeks on Poso Creek, then known as Ocoya Creek. Blake made some search in the near-by hills, and discovered some marine invertebrate remains and the teeth of sharks. He made drawings of the invertebrate fossils, which were afterwards submitted to T. A. Conrad, and which were described by him[2] from the drawings. The sharks' teeth were likewise submitted to Prof. Louis Agassiz[3] for identification and description, and the conclusion was reached by both Conrad and

[1] Pac. R. R. Rept., v. 5, pp. 32-36.
[2] Pac. R. R. Rept., v. 5, pp. 328-329.
[3] Pac. R. R. Rept., v. 5, 313-316.

Agassiz that the formation was of Miocene age. Blake described in detail the beds with which these fossils were associated to the thickness of about 160 feet, though he inadvertently conveyed the impression that they were a part of a series at least several hundred feet in thickness.

After the discovery of oil on the Kern River, Mr. W. A. Goodyear,[1] and later W. L. Watts,[2] both mention these formations. Mr. Watts gives a meager description of the beds occurring along the river, and lists of the fossils contained in them. Incidentally he leaves the impression that the beds have a thickness of at least 2000 feet, though he does not directly say so. The fossils collected by Watts were submitted to Dr. J. G. Cooper for identification.

Dr. Cooper[3] noticed the resemblance of some of the species to Pliocene and living forms, and concluded that either several periods were represented in the Kern River section, or that the series could only be described collectively as Neocene. The fossils, however, all came from about the same horizon.

In 1902 Geo. H. Eldridge[4] published a brief statement of the surface geology and structural features of the Kern River oil-field, giving by far the best description of the same that had yet appeared. He believed that the section contained both Lower and Upper Miocene beds, and perhaps also Pliocene. The structure he believed to be, in the main, monoclinal over a wide area, and to contain minor undulations resulting in subordinate folds, in which the dip was commonly below 10°. The entire series of beds, he states, has the appearance of a shore deposit along the granite range of the Sierra. The wells of the Kern River field, according to Eldridge, are drilled into the upper part of the series, though he does not specifically say so.

In 1904 Dr. J. C. Merriam,[5] in a brief paper on the Fauna of the Lower Miocene, recalled the fact that at least some of the Kern River beds are of that age, chiefly on the evidence of such forms as *Agasoma gravidum, A. kernianum, Turritella ocoyana,* etc. Incidentally he called attention to the fact that

[1] 7th Ann. Rept. State Min., 1888, pp. 67-68.
[2] Bull. No. 3, Calif. State Mng. Bur., 1894, pp. 38-41.
[3] Bull. No. 4, Calif. State Mng. Bur., p. 51 et seq.
[4] Bull. U. S. Geol. Surv. No. 213, pp. 310-312.
Bull. Geol. Dept. Univ. Cal. v. 3, pp. 377-381.

in a wider study of the subject there appeared to be two distinct horizons of the Lower Miocene in California.

In 1905 F. M. Anderson[1] published a brief note on the formations along the Kern River, stating their thickness to be about 3000 feet, and giving a list of some 38 species, including many characteristic Lower Miocene forms. The species listed were all from the same horizon, within a vertical range of 200 feet, but more than 1000 feet above the base of the Neocene.

Meanwhile Mr. John Barker, whose residence was for some years upon Kern River, collected a large number of fossil sharks' teeth and other vertebrate remains from near the same horizon, all of which were donated to the California Academy of Sciences.

Later F. M. Anderson collected an equally large number of similar remains from the same horizon, including many undescribed species, all of which were likewise donated to the California Academy of Sciences.

In 1907 Dr. David Starr Jordan[2] published descriptions of many new species of sharks and other fishes found in the collections of Barker and Anderson, but without any attempt to determine the exact horizon of the Miocene from which they were taken. In these collections there were nearly 800 specimens, representing perhaps 15 species, most of which were sharks, though including also remains of rays and skates. All of these collections were lost in the San Francisco fire.

As will be seen from the foregoing review, the literature bearing upon these beds is fragmentary and scattered, and although the formations are interesting and important, no one seems to have found time to give them the attention they deserve. It is hoped that in the following pages the measure of their importance will be more fully shown, and some further information gathered from their study.

Topography of the Area

Viewed from a distance, the topographic features of the area herein described consist of low rounded hills, which taken altogether present the aspect of a gently sloping mesa inclined

[1] Proc. Calif. Acad. Sci. v. 2, pp. 187-188.
[2] Bull. Geol. Dept. Univ. Calif. v. 5, pp. 95-144.

toward the west. From a nearer view they are seen to be very much dissected by erosion. The larger streams coming from the Sierra meander through the zone of foot-hills in sinuous valleys along narrow flood-plains developed by corrasion in the yielding sediments. The intervening parts of the area are deeply cut by canons and ravines of varying gradients, which reproduce, in measures proportionate to their size, the features of the larger streams. As the general mesa-like surface rises gradually toward the east, so too, in going upstream toward the basement formations, the canyons and their tributaries become deeper, and the hills higher and steeper. The effect is that usually produced upon yielding sandy formations by recent but rapid degradation. The topography is similar to much that is found in the more arid belt along the western border of the Great Valley.

The principal streams are the Kern and White rivers, Poso, Caliente and Tejon creeks, all of which derive their waters from the older areas of the Sierra, and descend thence through deep and narrow gorges, and enter the zone of foot-hills in rapids, below which the grade is quickly lost. With the exception of the Kern River, these streams are without water during the drier portions of the year, while in the wet seasons they are often torrential. They cross the zone of foot-hills in relatively wide and shallow canyons, and have developed flood-plains that are in strong contrast to the narrow defiles in the older and harder formations. The canyon of Caliente Creek offers some interesting features which will be taken up later.

River-Terraces

The later erosional phases in the physiographic development of the region are well illustrated in the terraces along the several streams in the zone of the Tertiary hills. They are to be seen along all of the larger streams, but especially along the valley of the lower Kern. Within four miles of the point at which the river emerges from the granitic defile, five distinct terraces are to be seen above the present level of the river. Most of these terraces are shown in the plates at the end of this paper. Within the limits of these views they are found at elevations of 20, 60, 100, 160 and 350 feet above the level of the river. There are terraces at still higher levels, and rem-

nants of terraces, though they can hardly be called stream-terraces.

The highest river-terrace proper is at an elevation of nearly 850 feet above the sea, and on the south side of the river forms a broad mesa with an undulating surface. This may mark the level of a late Pliocene or Pleistocene delta, which will be referred to later.

The various terraces here described probably represent former flood-plains of the river, developed during the gradual elevation of the region. River gravels are strewn abundantly over all of these terraces, and even river boulders occur on some of the ridges 700 or 800 feet above the floor of the valley. These topographic features are fairly well shown on the Bakersfield special topographic sheet of the U. S. Geological Survey.

Base-Leveling

As a topographic feature the development of base-level terraces on the valley border is not so conspicuous within the Kern River area as it is at some points just outside of its limits. As shown in some of the photographs of the neighboring foot-hills, they form recognizable features along the southern border of the valley, and, as stated in former papers, they are present along its western border. Over the greater portion of the Kern River area, erosion has obscured or obliterated them to a considerable extent, though undoubtedly the mesa-like topography of the foot-hills is partly due to base-leveling, at least in its higher levels.

On the south side of the Caliente Creek at about the altitude of Bealville is one of the more noticeable of these terraces. Terraces that are believed to be the result of base-leveling truncate the edges of the older Miocene beds to the north of the Kern River and Poso Creek, and also south of the river as far as the Tejon valley.

Geology of the Foot-Hills

The geology of the area as shown on the maps includes, broadly speaking, two series of rocks; the Neocene Tertiary and the basement series. This fact has been already mentioned by most of the writers who have alluded to this locality, and

it requires no special notice here. The older series consists of granitic and metamorphic rocks, among which are hornblendic and other crystalline schists, phthanites and limestones. The contact between the older series and the Neocene is usually well defined, so that the boundaries are easily mapped.

There are a few isolated areas of Neocene which are evidently superficial, and also a few unimportant areas of the basement rocks exposed by erosion within the boundaries of the Neocene. Moreover, the Neocene deposits occupy some troughs in the basement rocks which appear to have been excavated in pre-Neocene times. The most important of these troughs is that of the Caliente canyon which will be described hereafter.

The Neocene Series

The Neocene deposits extend along the foot-hills of the Sierra from near White River southward to the Tejon valley, forming a zone of varying width, fifty or more miles in length. This zone narrows at each end, though more gradually at the south, and has its greatest width in the section along Poso Creek.

As a feature of great economic value this area includes the well known oil-fields of the Kern River, which are situated near the mouth of the shallow canyon of the lower Kern River. But it is not the design to give prominence to the economic features of the geology in this paper.

Structure of the Neocene

The Neocene deposits of the Kern River area were evidently laid down upon a floor of older rocks that had been much eroded. This fact is illustrated by the somewhat broken boundary, by the isolated areas of granite within the Neocene, and by the filling of pre-Neocene troughs by the basal beds of the Neocene. This latter feature is particularly well shown in the case of the Caliente canyon. To some extent the dip and strike of the basal beds conform to these irregularities, but this is not usually noticeable.

In the main, the structure of the Neocene beds is simple, and consists of a gentle dip to the southwest, which rarely exceeds 5° or 6°. The greatest dip is near the base in certain disturbed

localities, and the flattest is along the western border of the hills. There are a few local undulations that develop low anticlinal arches elongated in a northwest and southeast direction. One of these anticlines traverses the developed oil district of the Kern River, and, according to Eldridge, another is found farther north. Another is to be seen along the eastern border of the area just north of the Kern River, and may be followed to the northwest across Poso Creek. It lies a little to the west of the fuller's-earth mine on the road from Poso station to Granite. There is a corresponding syncline to the east of this, midway between the Granite road and Adobe canyon.

The evidences of faulting within the Neocene area are almost negligible, though such faulting has taken place. Faulting to a greater extent has taken place along the eastern margin of the area, following in a general way, and in part, the contact with the basement rocks, and extending also at right angles to it for a limited distance at one point at least.

The faulting along the margin has evidently been of the normal type, and was probably progressive, resulting in a displacement of at least a few hundred feet in some places, and much more in others. At Pyramid Hill, the lowest Neocene beds known within the area are left exposed at a considerable elevation, resting upon a floor of granite. Near Walker Basin Creek, beds of sandy ash, which are apparently of Lower Miocene age, are severed from the main area and left stranded at an elevation of 2500 to 3000 feet upon the granites, indicating a throw of 1000 feet or more.

The structure of the Neocene beds developed by this faulting is partially expressed in the Poso anticline previously mentioned. It seems probable that the faulting has been progressive, and *pari passu* with the corrasion of such narrow defiles as that of the Kern River; but this aspect of the subject cannot be fully taken up at present.

North of Poso Creek, erosion has greatly excavated the Neocene sediments along the line of contact, forming small deep valleys in which the strata are clearly exposed.

In the head of Adobe canyon and near Granite station, where the structure of the Neocene beds resting upon or against the basement rocks is well shown, they are seen to be almost

horizontal, or to dip gently westward at a low angle. In this respect they present a strong contrast to their counterparts on the opposite side of the Great Valley, where the lowest beds of the Neocene usually stand at a high angle against the basement series.

The average dip of the strata across the entire area in the vicinity of Poso Creek is less than 4°, and approximates 3° 30′. This is about the average along a cross-section nearly 10 miles in length, and, as shown later, it fairly represents the dip in the western side of the developed oil-field.

The entire series has in many places the appearance of stratigraphic conformity throughout, and evidence is often lacking of any great disturbance intervening between the beginning and the close of Neocene sedimentation. Both to the north and to the south of the Kern River, however, there is an evident overlap of the younger portion of the series upon the older, and even upon the basement rocks to the east. Along Caliente Creek and southward, the Neocene beds stand at a higher angle than elsewhere; and beds that belong to the upper part of the series rest upon the basement rocks. Northward, near White River, there is a similar overlap. Beyond the limits of this area the evidence of overlapping is unmistakeable, but within the area it took place by a process so gradual that the results are not striking.

There is no clear proof of an interval of erosion intervening; though the assumption of one might offer a convenient explanation for the comparatively small stratigraphic thickness as contrasted with similar beds near Sunset, Temblor and northward.

THICKNESS AND STRATIGRAPHY

On account of the excellent exposures of the strata, and from the fact that deep wells have been drilled in the western part of the area, the opportunity for studying the thickness and composition of the Neocene beds is exceptionally good. Two sections have been made across the area, and two or more deep wells have given a fair representation of the stratigraphy. One of the sections crosses the area north of Poso Creek; the other extends along the Kern River; and both show some peculiarities. The aggregate thickness of the entire series, as measured in the outcrop across the strike to the north of Poso

Creek, is quite 3300 feet, and may be more, assuming the beds to have been originally horizontal.

Near the Kern River, where the dip varies from 2° to 8°, the measurement of its different parts separately gave an aggregate thickness of 3250 feet; yet the apparent thickness may be somewhat deceptive because of faulting.

In the deep wells the thickness is naturally somewhat less, since their positions are farther from the shore line, and the section is also somewhat reduced by erosion, but these matters will be referred to later.

The Outcrops.—Within the area outlined, the sediments of the Neocene are prevailingly sandy in the outcrop, with only a moderate proportion of clay and organic shales, such as usually compose them in other parts of the coast country.

Toward the bottom of the series there are conglomerates, sands, and volcanic ash, making up near 600 feet of the lower portion. Higher up and extending above the middle of the series there are shales more or less sandy in the outcrops, or shales interstratified with sands, that make up in the aggregate a third of the series. Above the shales are sandy beds which become generally coarser toward the top, as will be shown later. It is thus possible, on the basis of lithology, to separate the combined series into three separate portions; but on other grounds a two-fold division has been here presented.

In the outcrops the clastic elements are prominent in nearly all parts of the series, and the first impression is apt to be that it is chiefly sandy. At the surface the beds are but little consolidated, as the results of erosion show. The harder beds are nearly all confined to the lower third of the series, and they are prominent only at the base and near the bottom.

The lithological character of the individual beds is probably not always persistent over wide areas, and it is not easy, therefore, to recognize the smaller stratigraphic units in widely separated localities.

Below is given a tabulated generalized statement of two sections crossing the area, and similar stratigraphic columns of two deep wells of the Kern River district for purposes of comparison.

Fossils have been found at several different horizons in the lower part of the series, but more especially at three separate

levels designated in this paper as Zones A, B, and C, which are shown in their relative positions in the following statement:

Poso Creek Section		Santa Fe Well, "Rasmussen," No. 28		Grace Oil Co's Well, No. 5		Kern River Section	
			Erosion.		Erosion.		
240′	Pink sands, gravels, etc.					Terrace gravels.	240′
				400′	Gravels and sands with water.		
	Gray sands, gravels, etc.	300′	Gravels, sands and clays.		Sands with interbedded clays, etc.	Gray sands, gravels, etc.	
975′	Green and brown sands, gravels, and beds of clay.	605′	Kern oil-measures, etc.	905′	Sands with oil and gas. (Kern oil-measures.)	Green and brown beds.	1260′
			Oil-sands.		Water-sands, oil-sands, etc.	Clays, sands, and gravels.	
						Sands and gravels with stains of oil.	
	Ashy beds, "fullers' earth,"		Sandy blue clay and shale beds.		Clay shale.		
255′	sands, etc. with marine fossils.	720′		900′	"sticky shale," gas, etc.	Zone C. Sands, shells, sharks' teeth.	60′
	Ashy shales.		White sands and clays.		Sandy shale, clay shale, etc.	Clays and ashy shales.	700′
	Fine white sands and clays.					Yellow clays and sands.	
1125′			Brown sandy shale, etc.				
	Sandy shale with marine shells.	955′	Brown shale.			Zone B. Sands, marine shells.	100′
					Marine shells.		
100′	Sandy shale, marine shells.		Brown sandy shale, etc.		Organic shale.	Diatomaceous shale, sandy clays, shale, etc.	440′
					"Lake of Mud."		
350′	Arkose sand and rhyolite ash beds.	5′	Sand, salt water and marine shells.	961′	Sand and shale with oil and gas.	Zone A. Sands, marine shells.	160′
					Shale with gas.		
250′	Coarse arkose sand and gravels.	220′	Hard sands.		White sand.	Sandstones, basal conglomerate.	300′
3295′	Total	2205′	Gray shales, sands, and brown shale.	3166′	Total	Total	3260′
		5010′	Total				

Deep-Well Records.—The records of the deep wells shown above throw considerable light upon both the thickness and the stratigraphy, as well as upon the structure of the Neocene series, and deserve, therefore, more than a passing notice. Mr. W. L. Watts[1] gives the record of a well drilled on the Barker ranch upon the Kern River, which began in a stratum of shale near the top of "Zone B," and which was carried to a depth of more than 969 feet without reaching the base of the Neocene, though boulders are reported at 743 feet from the surface. Most of the strata described in the record are sandy clays and hard shales such as are found on the surface not far eastward. Drilling was still in progress at the time of this report, and later developed a strong flow of sulphur water, which presumably was near the base of the series. The flow of water still continues, and is characterized by its contents of H_2S gas, and alkaline sulphates and chlorides.

Subsequently the deep well of the Grace Oil Company[2] was drilled on Sec. 8, T. 29 S., R. 28 E. near the Kern River, in the western part of the district. The surface at this point has been reduced by erosion not less than 240′, and the well penetrated the formations to a depth of 3166 feet, reaching a bed of white sand apparently near the base of the Neocene, from which was obtained a strong flow of very salt water.

On account of the more than usually complete information furnished concerning the drilling and the formations of the Grace well, it is of more than ordinary interest. The following notes and extracts are taken from a written statement by Mr. F. J. Carman, who superintended the drilling of the well.

The upper part of the log is said to be not unlike other logs in the vicinity, and includes the usual clays, sandy strata, and oil-sands of the Kern River district. Oil-sands are reported at intervals below 1260 feet, but only in small quantity, or even with some doubt.

At 2206 feet a bed of sand with fragments of fossil shells is reported, and its position corresponds somewhat to that of "Zone B" of the Kern River section.

[1] Bull. No. 19, Calif. State Mng. Bur. p. 116.

[2] The log of this well with some others will be added at the close of this paper, and for those who desire to make a close study of the stratigraphy of the district they will be found valuable.

Mr. Carman says: "At 2260 feet a lake of mud was encountered; this was the soft top of a shale formation 888 feet thick. This shale was soft but not sticky, most of the pieces obtained showing distinct lamination, and all of it saturated with hydrocarbon gas which would burn at the mouth of the well."

"The change at 2260 feet was a distinct one, from alternating sand and shale to a continuous shale deposit of great depth, and of somewhat different character from the upper shales. From what Captain Barker told me I should judge that this same shale was struck on his ranch at about 1200 feet."

"The shale also carried occasional streaks of chert and limestone from a few inches to two feet thick. The shale itself was slightly calcareous, probably due to the infusorial remains. A high-power microscope showed these minute shells, though I do not know their names."

"Some of this shale from about 2600 feet was identical in appearance with a piece from one of the Santa Maria wells at about 2000 feet, though I do not imagine this identifies the formation. At places in this shale, notably just beneath the hard shells, small quantities of oil were observed; I should judge it was from 20° to 25° gravity."

"At 3148 feet soft, fine-grained, white sandstone was struck into which we drilled 18 feet." The drilling was then said to have been stopped, "by the strong current of salt water that began to flow as soon as we had penetrated a short distance into the sand."

"This water was quite salty, though not so much so as ocean brine. It contained no sulphates."

"This flowed gently over the casing. How high it would have risen above this I do not know."

"The sand we found at the bottom, * * * is very similar to that found a few miles east of Poso station."

"From 1100 feet to 1285 feet the sands contained mainly water. At this point 55 feet of extremely coarse sand and gravel was struck, heavily saturated with oil of 10½° gravity, and no water."

"The find of this stratum, containing no water, led me to believe that I was upon the summit of another oil-horizon, especially after passing through so much water above."

At a later date a well was drilled by the Santa Fe Railroad Company in the western part of the Kern River field near the center of Sec. 24, T. 28 S., R. 27 E. It attained a depth of only 2270 feet, and was then abandoned. The formations penetrated by this well were for the most part sandy beds with interstratified clays described in the log as "blue clays." Only a little oil-sand was reported above 1260′, and less still below that depth. Many of the sandy beds carried water which required frequent shutting off in drilling the well.

Most of the productive oil-wells in the Kern River field have penetrated only the upper member of the series, and but few have attained a depth of more than 1250 feet. The records show the beds to be mainly sand and sandy shale, which are separated by beds of clay distributed at intervals in the formation. Very little oil has been found below a depth of 1250 feet, though the deep-well records report small quantities at a much greater depth.

In 1909 the Santa Fe Railroad Company under the name of the Petroleum Development Company drilled a deep well, "Rasmussen No. 28," on the S. E. ¼ of Sec. 4, T. 29 S., R. 28 E., and at the time of this writing had not ceased operations upon it. Through the kindness of Mr. F. C. Ripley, superintendent of the company, permission was obtained to make use of the following facts and records.

In the upper part of the log the formations are chiefly clays and sands with the usual oil-sands of the district. Oil in paying quantities was not found below a depth of 905 feet from the surface.

At a depth of 2694 feet the drill entered a hard sandstone from which was obtained a strong flow of salt water. At 2805 feet a dark gray shale was reached which continued almost uninterruptedly for nearly 2000 feet. This formation of gray shale resembles very much the dark shales of the Eocene in the vicinity of the Tejon ranch, in the San Emidio hills. Fossils were brought up from a depth of near 2600 feet, including *Turritella ocoyana,* and *Chione temblorensis.* The sandy bed between 2694 and 2805 feet apparently marks the base of the Miocene.

As will be seen, the thickness of the Neocene series is here also somewhat reduced by erosion—probably by as much as 450

feet, including the gravel beds at the top represented in the bluffs south of the river.

The dip of the beds between the deep wells, Rasmussen No. 28 and Grace Well No. 5, is near 3°, and as calculated on a section more nearly normal to the strike, it must be as much as 3.5°.

Estuarine Conditions

It is clear from the foregoing descriptions that the Neocene deposits of the Kern River are largely marine. At least one prominent exception to this rule must be noted, and the facts presented in this exception are of more than passing interest. The pre-Neocene trough of the Caliente Creek, especially near the junction of the Caliente and Walker Basin creeks, is filled with sediments that are at least not altogether marine. More than 2000 feet of strata are exposed along the lower part of Walker Basin Creek, nearly all of which are either non-marine or brackish-water deposits; and some of the strata near the base are plainly of fresh-water origin. The series is almost entirely composed of coarse gravel and sand of a greenish drab color, partly unconsolidated, but in the main sufficiently hard to resist weathering. Much of the material is pumiceous and otherwise volcanic.

Near the base of the series are sandy clays of a soft and yielding character and of the usual greenish color, containing remains of land and fresh-water mollusca; and, higher in the series, similar clays containing leaves and stems of plants. Near the top a flow of basaltic lava some 90 feet in thickness can be followed for a distance of two or three miles. Above the lava, and forming the uppermost beds of the lower group, are about 190 feet of marine strata.

The whole collection forming the lower group dips southward at an angle of 20°-30°, as exposed on the northern border of the trough. The character of the sediments, their distribution, the character of their fauna, and the plant-remains found at various levels, all indicate that the beds are estuarine, and are either of fresh-water or of brackish-water deposition.

This view is strengthened by the position of the beds within a trough in the basement rocks, and also by the fact that, as

followed toward the northwest, the beds pass into the normal marine conditions of the lower Miocene already described.

Overlying this brackish-water series above described are the beds of the Kern River group forming a wide overlap.

DIVISIONS OF THE NEOCENE

In the foregoing descriptions it has been shown that, upon the basis of lithology, the Neocene series can be divided more or less satisfactorily into three groups, two of which are thick, sandy aggregates separated by a third, in which clays and organic shales form a prominent part, constituting probably half its volume. If, on the other hand, the division is based upon other criteria it is not easy to separate the two lower members, though the upper one remains distinct.

On the whole the most natural division accords with the data of paleontology, and as measured in the outcrops is roughly as follows:

		Gravels and sands,	250′
Neocene	Kern River Group.	Green and brown beds, gravels, sands and clays, without fossils, but including the Kern oil-measures.	1260′
	Unconformity		
	Temblor Group.	Lower Miocene; clays, ashy beds, shales, white and yellow sands with marine fossils;	1160′
		Sands, sandy ash-beds, pumiceous ash-beds, and conglomerate, with marine fossils.	600′
		Total Thickness,	3270′

THE TEMBLOR GROUP

Basal Member.—The basal division of the Neocene series, like the upper division, is essentially sandy; but, unlike the latter, the rocks are often considerably indurated, and sometimes concretionary. Fossil invertebrates are often abundant, and have doubtless contributed cementing material to the concretions and to other hard portions of the strata. Some of the lower beds consist largely of volcanic ash, pumice, and sand, as has been already noticed by previous writers, and in this paper. Basal conglomerates are visible in only a few places, but a stratum of at least 50 feet is exposed at one

point north of the Kern River. Conglomerates, sandstones, and ashy beds make up 350 to 600 feet of the series to the north of the Kern River. On the flanks of the granite along Comanche canyon, beds of coarse sand and conglomerate make up 250 feet or more; but it is probably not all exposed. Gravelly or pebbly beds can be followed southward to the Tejon valley, but positive statements cannot now be made concerning them.

In the outcrop the basal member is not always visible, but between Poso Creek and White River, where it is exposed, it consists chiefly of coarse arkose sand mingled with rhyolite ash. The lowest bed, 250 feet in thickness, is a coarse white quartz sand, usually unconsolidated, though locally becoming indurated to quartzite.

Above this is a characteristic aggregate of beds 350 feet thick, in which ash is much more conspicuous, and strata of ashy sand alternating with beds of white ash in which grains of quartz and dark mica form a minor part. Some of the beds are entirely of ash of a faint dirty green color, yielding reluctantly to erosion, and for that reason forming the capping of prominent narrow ridges with bold eastern escarpments between the drainage lines.

Between Poso Creek and the Kern River, where combined faulting and erosion have exposed the lower beds, there are basal conglomerates and concretionary sandstones near 500 feet in thickness, mainly detrital, in which ash is not prominent, though probably not absent. These beds are best exposed in Pyramid Hill where they are quite fossiliferous, containing many species of marine invertebrates, and the teeth and bones of many vertebrate species.

To the south of the Kern River these basal beds are not much exposed, or, if exposed, were not recognized beyond a limited distance. It is evident that as the basal beds are followed northward they lose more and more their detrital aspect, and become more and more ashy and at the same time less fossiliferous.

To the north of Poso Creek, marine fossils are to be found in many places in these lower beds, though they are not abundant. Immediately below, however, and sometimes in, the more ashy beds, the teeth and bones of marine vertebrates

are sometimes plentiful. Marine invertebrates, which are abundant south of Poso Creek, are much less abundant to the north.

On Caliente Creek, and about the junction of this stream with Walker Basin Creek, sands, gravels, and conglomerates make up a much larger part of the series, but the conditions here are in several respects local, as will be shown later. Volcanic materials make up a considerable part of the entire Temblor group in this locality.

To the north of the Kern River the concretionary beds of the basal member are usually more fossiliferous than other parts of the strata, and probably for that reason are harder and more resistent. In the weathering of the beds, however, the concretions usually disintegrate somewhat, often releasing the fossils in almost perfect condition.

As far as can be determined from well-records, this member of the Neocene series is much thinner in the western part of the field than in the outcrops; and this is not surprising, since the westerly stations represent points that were farther off shore.

Upper Member.—The upper member of the Temblor group, or the portion above the general level of 600 feet from the base, as shown in the outcrops and in the records of the deep wells, contains a smaller percentage of sand and other detrital matter, and a greater percentage of organic material than any other portion of the Neocene. And of the detritus present a greater portion is of clay and shaly matter.

In this member clays and shales probably form in the outcrop about 50 per cent of its volume, and of this percentage about one-half is organic. Some layers are chiefly composed of diatomaceae and other minute organisms. In the deep wells the sands are replaced by clays, and the strata are correspondingly reduced in volume, but more strongly characterized. The reason for this is to be found in the relation to the Miocene shore line. The percentage of organic matter in the strata is of course not readily known from the well-records, but that organic matter is present has already been shown.

Thick deposits of diatomaceous and other predominantly organic shales, such, for example, as the white siliceous shales

so characteristic of the Neocene in many parts of the coast region and in the Mt. Diablo Range, are almost absent from the deposits of the Kern River area. Microscopic organisms are not conspicuous in many of the strata examined, though in moderate numbers they are visible in many places.

At Barker's ranch on the Kern River, just below the beds designated as Zone B, there is an exposure of about 200 feet of white, chalk-like shale in which diatoms are readily seen with a lens, and there are a few other such outcrops north of Poso Creek; but there is in this area no body of strata comparable in thickness to the great beds of siliceous shale on the opposite side of the valley almost west of the Kern River. In place of such material, however, especially in the northern part of the area, there is a considerable quantity of white, or light-colored, ash, such as will be described in the following paragraphs.

Among the strata that may be especially mentioned are beds of a sandy clay-like rock which has been described as "fuller's earth." A critical examination of these beds and of their material has not been attempted, but, from a cursory examination of the rock and of the beds, it seems probable that the clay-like matter is residuary. The color, fracture, gravity, and other physical properties, and the appearance of the rock under a good lens, all conform to the characteristics of a sandy volcanic ash. It shows a decided ability to resist weathering, even after being mined. In color it is a light gray, with a faint greenish tinge.

An analysis of this material from an old "fullers' earth" mine opened on Sec. 14, T. 27 S., R. 28 E., published by the California State Mining Bureau,[1] gives the following composition:

Silica (SiO_2)	54.32
Alumina (Al_2O_3)	18.88
Iron oxide (Fe_2O_3)	6.50
Lime (CaO)	1.00
Magnesia (MgO)	3.22
Loss by ignit.	11.86
Alkali by difference	4.21
	99.99

[1] Bull. Cal. State Mng. Bur., No. 38, p. 275.

A sample of similar material taken from near the same place was analyzed by Dr. A. S. Eakle, of the University of California, and was found to correspond very closely in composition to a true volcanic ash with an admixture of quartz sand and some other foreign minerals. His analysis, given below, differs from the foregoing in a manner that may be largely accounted for in this way. With a good magnifier nearly all of the samples showed clastic matter of this sort mingled with the ashy products, and the sample analyzed was not exceptional, but fairly representative of the great mass of this rock. It was taken from an old mine a few miles north of Poso station on the road to Granite. Dr. Eakle's analysis follows:

Silica (SiO_2)	64.23
Alumina (Al_2O_3)	17.85
Ferric oxide (Fe_2O_3)	4.25
Lime (CaO)	4.01
Magnesia (MgO)	Trace
Potash (K_2O)	1.53
Soda (Na_2O)	1.98
Ignit.	5.33
	99.23

In the rock opened by mining there are casts of marine invertebrates, bones of marine vertebrates and the teeth of sharks. The lens reveals many minute scales of dark mica, and the confused granular surface of decayed felspathic matter and quartz sand. Several beds of this or similar material occur in this member of the Temblor, especially north of Poso Creek, where they form prominent outcrops at the surface, which are easily followed along their strike.

A few outcrops of sand are sufficiently bituminous to induce drilling for oil, which has been done in different parts of the district, but thus far without satisfactory results.

The fresh-water or brackish-water facies of the Neocene which was described some pages back, forms a local phase of the Temblor group. The difficulties to be overcome in making any division of the Temblor group upon the basis of lithological character become apparent when attempted in this quarter of the field. The more shaly portion is nearest the base, and the beds become coarser toward the top, though clays are distributed throughout the column.

Then, as will be shown presently, there is reason to regard the whole collection of fossiliferous beds as representing the whole of the Temblor group, though it is not proved that some part of the series has not been carried away.

The Kern River Group

The uppermost group of the Neocene, as far as known, is almost without fossils, and consists of sandy beds, alternating aggregates of sands and clays, and, toward the top, beds of gravel. These beds are well exposed in outcrop one or two miles east of the Kern River oil-field, and along Cottonwood Creek, and southward, and on the Caliente, and also north of the Poso stage-station on the road to Granite. Beds of gravel and conglomerate, and frequently large boulders, are characteristic of this group. Some of the boulders near Cottonwood and Caliente creeks are above a ton in weight.

The upper part of the group is usually gray in color, but the larger part has a characteristic pale greenish or sometimes yellow color, though it often contains thin strata of chocolate-brown sand or clay.

The entire group bears evidence of being a terrigenous rather than an organic deposit, as far as known from its outcrops and from the well-records of the Kern River district. What it may be beneath the valley floor can only be surmised, though very likely its organic component becomes more pronounced, and the detrital is reduced.

The thickness of the group varies somewhat in different parts of the area, though in general it is under 2000 feet. To the north of the Kern River estimates have generally resulted in placing it near 1260 feet. South of Cottonwood Creek a partial section was measured which had a thickness of over 1100 feet, and on Caliente Creek a calculation based upon the average dip showed a thickness of something more than 1500 feet. Its thickness is naturally greater in the western part of the area than in the eastern, where it has usually suffered from denudation.

The group often exhibits sudden alternations of condition, changing quickly from clays, shales, etc., to coarse gravels and boulders. Some of the boulders of granitic rock are so

large as to suggest glacial or other unusual conditions during sedimentation.

There is quite generally the appearance of stratigraphic continuity in the Neocene series, and at any one point it is not easy to detect any angular divergence in dip or strike between the Kern River and Temblor groups. When followed along the strike, however, there is conclusive evidence of overlapping and of unconformity between the two groups.

Just south of the Kern River, and also near White River, the Kern River group rests upon and covers in turn different members of the older group, and finally rests directly upon the granite. The same is probably true to the north of the Tejon valley.

Special importance is attached to the stratigraphy and distribution of this group from the fact that the productive oil-measures of the Kern River district are confined to it. From this fact it has been called the *Kern River group.* The oil-measures make up about one-half of the stratigraphic volume of the beds.

Very little oil, and probably no oil in commercial quantities, has been found in the Kern River field below the base of this group, though small quantities of oil and gas are often reported. Bituminous matter in small quantities has often been seen in some of the outcrops of the older group, but as indications of oil deposits they are generally negligible.

The age of the Kern River group is not readily told, except that it is younger than the Temblor, with which it is certainly unconformable, as already stated.

The only fossil remains that have yet been discovered in it are fragments of petrified wood, but aside from suggesting fresh water conditions, or perhaps those of shallow water, they are of little value.

The oil-measures furnish a sort of evidence, which is perhaps stronger than a suggestion, that the group should be correlated with the petroliferous beds at Sunset, Midway and McKittrick, but this topic will be deferred for the present.

Quaternary Deposits

Overlying all of the older formations of the lower Kern River region, including the basement rocks and the Neocene,

and resting more or less horizontally across their edges where they are upturned, are thick deposits of gravel of distinctly alluvial origin belonging to a former epoch. Their areal extent is difficult to estimate, but they occur along all of the larger streams and stream-terraces, and along the borders of the valley plain are blended with recent alluvial deposits of the Kern valley.

The most characteristic of these deposits have some elevation above the present stream beds, and from these they range upward in altitude to several hundred feet. A large area of these alluvial sands and gravels occurs along White River, and another about the lower portion of Caliente Creek; but these areas are probably among the more recent. Along the upper terraces of the Kern River are some of the older deposits. The more recent deposits are naturally the thickest, having suffered less from denudation. Near Bena, a small station on the Southern Pacific railroad, they form cliffs of horizontally stratified gravels nearly 100 feet in height, but probably these represent only the upper portion of the deposits, and their true thickness at this place is quite unknown. They rest in turn upon the upturned edges of both the Temblor and the Kern River groups, and clearly occupy a trough excavated in these formations prior to the epoch of alluviation.

These alluvial deposits vary in texture from coarse gravels to sands and clays, and have usually a rusty yellow color. For the most part they are incoherent, though near the summit a hard layer is often seen, which has served to protect the cliffs from reduction.

The denudation and excavation of the older groups prior to alluviation is interesting, as showing a relative elevation of the land surface, very probably above the present altitude; and the formation of alluvial deposits that are now elevated shows as clearly a corresponding depression of the land surface. Alluviation and terracing have doubtless been synchronous.

Faunal Features of the Series

The faunal contents of the Neocene series of the Kern River and its vicinity present some interesting and unexpected features. Blake's collections were probably made from the

lower fossiliferous beds of the series, but he was unable to arrive at any more definite conclusion than that the beds were of Middle Tertiary, or Miocene age. Whitney and Gabb came only to the same general conclusion as to their age. Dr. J. G. Cooper, after examining several small collections made by W. L. Watts, partly from the lowest horizon, though chiefly from one higher up, was able to classify the beds only as Neocene. Among the fossils from the vicinity of Barker's ranch he believed he had identified many living species, and evidently these influenced his determination of their age. Later J. C. Merriam expressed a belief that the beds containing *Turritella ocoyana* and two or more forms of *Agasoma,* etc., were of Lower Miocene age, and refers to the Kern River beds as examples of the same. It is due also to remember that Dr. Merriam recognized the occurrence of many species in these beds having a modern or recent aspect.

In accordance with the views already expressed in this paper, only the lower 2000 feet of strata can confidently be called Miocene, as only that part of the series is known to be fossiliferous. Within this range, fossils are found at different levels throughout the area, some species having the entire vertical range. *Dosinia whitneyi, Chione temblorensis, Pectunculus septentrionalis,* and *Neverita callosa* have been found at both the top and bottom of the fossil-bearing strata. *Pecten andersoni, Venus pertenuis,* and *Solen sicarius* have a considerable vertical range. But by far the larger number of species and individuals are found in a much more restricted range.

There are, as already suggested, three well-marked horizons, separated by intervals of more than 400 feet, which contain nine-tenths of the fossils and an equal proportion of the species. These horizons have been designated as Zones A, B, and C.

Zone A is that of Pyramid Hill on the divide between the Kern River and Poso Creek. It is apparently the horizon described by Blake, and the one from which he collected the species described by Conrad, and it constitutes the lowest known fossiliferous horizon of the series. The top of Zone A is not more than 500 feet above the base. The beds are somewhat concretionary and exceedingly fossiliferous.

Zone B is that of the Barker's ranch locality, best seen on the north bank of the river one mile above the old ranch house.

It is the horizon chiefly represented in the list of species published by the writer in 1905, and is also the horizon from which Dr. Cooper believed he had obtained many living species. Probably none, or only a few, of the species are actually living, though it must be admitted that the resemblance of many of them to living forms is more than superficial. Probably many of them are the lineal antecedents of forms now living along the Pacific coast. Zone B has a stratigraphic thickness of less than 150 feet, and may be generally taken as 100 feet, though some of the species are found a little lower.

Zone C is that exposed near the top of Round Mountain, two miles north of Barker's ranch, and also in the hills west of Round Mountain, locally known as the Shark-Tooth Hills. It is the horizon from which most of the sharks' teeth have been obtained, including those to which reference is made by Dr. Jordan.[1]

This horizon can be followed across the field for many miles, and can usually be identified by its characteristic white marl, by its abundant sharks' teeth, and by the fact that it forms the uppermost fossil horizon, and is overlain by the greenish-gray sands of the Kern River group.

On the following pages are given lists of the more common or characteristic species of the three principal horizons of the Kern River Neocene series. The fossils of Zone A were collected by W. H. Ochsner, A. G. Carpenter, and the writer from the south side of Pyramid Hill in 1909.

LIST OF SPECIES

Species from the Kern River section:	Miocene Fossil Zones		
	A	B	C
Arca montereyana OSMONT	×	×	
Cardium vaqueroënse ARNOLD	×		
Cyrena (*Corbicula*) *dumblei* ANDERSON	×	×	
Cytherea (*Callista*) *mathewsoni* GABB	×	×	
Cytherea sp.		×	
Dosinia conradi GABB	×	×	
Dosinia whitneyi GABB	×	×	×
Homomya sp.	×	×	
Leda oregona SHUMARD		×	
Mactra (*cf. M.* albaria CON.)	×		
Mactra (*Spisula*) (*rel. M. falcata* GLD)		×	
Mactra sp.		×	
Mytilus mathewsoni GABB	×		

[1] Bull. Dept. Geol. Univ. Cal., v. 3, pp. 95-144.

LIST OF SPECIES—Cont'd.

Species from the Kern River Section:	Miocene Fossil Zones		
	A	B	C
Mytilus (small sp.)	×		
Ostrea eldridgei ARNOLD	×		
Ostrea sp. (rel. O. titan CON.)	×		
Ostrea sp. (small thin valves)	×		
Pecten andersoni ARNOLD		×	×
Pecten bowersi ARNOLD	×		
Pecten magnolia CONRAD ?	×		
Pecten nevadensis CONRAD	×		
Pecten perrini ARNOLD ?	×		
Pecten sespeënsis ARNOLD	×		
Pecten sp. (rel. P. estrellanus CON.)	×		
Pectunculus branneri ARNOLD	×	×	
Pectunculus septentrionalis MIDD	×		
Phacoides acutilineatus CONRAD	×		
Phacoides richthofeni GABB		×	×
Pinna alamedaënsis YATES	×		
Solen sicarius GOULD		×	
Solen sp.	×	×	
Tellina ocoyana CONRAD	×	×	
Tellina sp.	×	×	
Tevela inezana ARNOLD	×	×	×
Venus (Mercenaria) pertenuis GABB	×	×	
Venus (Chione) temblorensis ANDERSON	×	×	×
Yoldia sp. (rel. Y. cooperi GABB)	×	×	
Agasoma gravidum GABB	×	×	
Agasoma kernianum COOPER	×	×	×
Bullia (Molopophorus) anglonana ANDERSON		×	
Cancellaria condoni ANDERSON		×	
Cancellaria dallana ANDERSON		×	
Cancellaria joaquinensis ANDERSON		×	
Cancellaria pacifica ANDERSON		×	
Cancellaria simplex ANDERSON		×	
Chrisodomus sp.	×		
Conus owenana ANDERSON	×	×	×
Crepidula praerupta CONRAD		×	
Crepidula princeps CONRAD	×		
Cuma biplicata GABB		×	
Dentalium substriatum CONRAD		×	
Dentalium sp.	×	×	
Epitonium (Opalia) (cf. O. rugiferum DALL)	×		
Nassa arnoldi ANDERSON		×	
Natica (rel. N. lewisi GOULD)	×		
Neverita callosa GABB	×	×	×
Oliva californica ANDERSON		×	×
Oliva futheyana ANDERSON		×	
Pleurotoma (Clathurella) dumblei ANDERSON		×	
Purpura lima MARTYN	×	×	
Scaphander jugularis CONRAD		×	
Sigaretus scopulosus CONRAD		×	
Terebra cooperi ANDERSON		×	
Trochita filosa GABB		×	
Trophon kernensis ANDERSON		×	
Turritella ocoyana CONRAD		×	

Species cited by Blake as determined by Conrad from the Lower Miocene of Ocoya Creek:

Natica genticulata CONRAD
Natica ocoyana CONRAD
Scaphander jugularis CONRAD
Agasoma gravidum GARB (*figured but not named*)
Agasoma kernianum COOPER (*figured but not named*)
Pleurotoma transmontana CONRAD
Nassa arnoldi ANDERSON (*figured but not named*)
Sycotypus ocoyanus CONRAD
Turritella ocoyana CONRAD
Colus arctatus CONRAD
Crepidula prærupta CONRAD (*figured only*)
Tellina ocoyana CONRAD
Pecten nevadensis CONRAD
Pecten catilliformis CONRAD
Arca microdonta CONRAD
Dosinia sp.
Cardium sp.
Solen sp.
Venus sp.
Cytherea (*Callista*) *mathewsoni* ? GABB

Fossil Fishes determined by Dr. Jordan from the Lower Miocene of Kern River:

Carcharias antiquus AGASSIZ
Carcharodon branneri JORDAN
Carcharodon rectus AGASSIZ
Dalatias occidentalis AGASSIZ
Galeocerdo productus AGASSIZ
Hemipristis heteropleurus AGASSIZ
Heptranchias andersoni JORDAN
Isurus planus AGASSIZ
Isurus smithi JORDAN
Isurus tumulus AGASSIZ
Lamna clavata AGASSIZ

The species contained in the foregoing list are mainly from the top of the Temblor, or the horizon of Zone C, and were collected by the writer or by Mr. John Barker as before stated. In addition to the above species there are many remains of rays, skates, sword-fish, and other marine fishes and animals. Vertebrae and other bones of whales, and the jaws, teeth, and ribs of marine mammals are occasionally found. Teeth of sea lions and of *Desmostylus* have also been found among the fossils of Zone C.

According to Blake's statement, the species described by Agassiz were, with perhaps two exceptions, obtained from a lower horizon on Poso Creek; but as far as known to the writer, the most prolific beds are at the upper limit of marine shells. The beds of this horizon are probably the most per-

sistent in character, and can be followed farther through the field than any others that have been attempted. A prominent layer of white sandy marl with an abundance of vertebrate remains can be followed easily for many miles.

Mr. Charles Morrice has recently collected from a small area in this zone an enormous number—1500 or more—of vertebrate fossil remains, including the teeth of many species of sharks and skates, the jaws and teeth of sea-lions, bones of whales, etc. Some of the sharks are probably undescribed species. Teeth of a *Desmostylus* have been obtained also from the same locality. It seems remarkable that so many remains, including diverse species, could be assembled in so small an area, which, at the time of their deposition and burial, must have been considerably off shore. Probably they mark an epoch of abnormal destruction among marine veretebrates, possibly an epoch of violent volcanic activity accompanied by the fall of ash, etc.

As has been already stated, the teeth and other remains found at other horizons than Zone C, are often found just beneath beds of volcanic ash, or in beds in which ash makes up an important part.

As will be seen, the faunas of the three prominent zones already described belong to the lower division of the Neocene, and are characteristically Lower Miocene. The upper division as far as known is almost without fossils, and is barren of any forms that are serviceable for stratigraphic correlation.

Fossils from the Estuarine Beds

Among the invertebrate fossils occurring in the estuarine beds of Caliente Creek, Dr. Dall has recognized land shells belonging to the genera *Circinaria* and *Epiphragmophora.* In addition to these a species of *Corbicula* near C. *dumblei* occurs in great abundance in one or more beds near the top of the series.

No special effort was made to collect or to determine the land plants contained in these beds, though, along with ferns, etc., the following genera were recognized: *Salix, Platanus, Ficus.* Other genera, however, were observed and also collected.

Correlation of Deposits

In a recent paper on the Geologic Record of California,[1] Dr. J. Perrin Smith has made a tabulated statement of the recognized sedimentary groups of California, including a summary, and tentative correlation of the formations that have thus far been described in the Neocene deposits. This is undoubtedly the most concise and satisfactory statement that has yet appeared of the progress made upon the correlation of the Neocene in California, though it evidently leaves much to be settled. The standard column of the Neocene is still a debatable subject, and will probably remain so for some years.

As shown in former papers bearing upon the stratigraphy of the valley borders, and as shown also in the tabular summary of Dr. Smith, here reprinted, there are, in the Mt. Diablo Range taken as a whole, all of the horizons of the Neocene, or their equivalents, that are to be found in any part of the coast, or in other words, all that are required for a complete section; though there are few places, if any, in which they are all present in recognizable form. At one point the lower, at another the middle, and at still another the upper members of the series are more fully developed. In the Kern River region if all of the members are present, they have not been recognized, and there appears to be the same incompleteness of section.

While it is possible or perhaps easy to identify some of the beds with members of a standard column, it is at present not safe to attempt a complete correlation of the several groups in the Kern River Neocene with those even of the Mt. Diablo Range. There is great variability in both the lithology and the faunas of contemporary beds even within the limits of the basin here concerned. For example, the Neocene deposits on the west side of the valley near the Temblor ranch and near Sunset have a thickness estimated at more than 6000 feet, consisting chiefly of shales which are largely organic. The contemporaneous strata near the Kern River attain hardly more than half this thickness, and are mainly of sandy detritus, with beds of ash and a minor part of shale, not exclusively organic. On the west side of the valley the beds are fossilifer-

[1] Jour. Geol., v. 18, 1910, pp. 216-227.

ous in places, even to near the top; while on the Kern River side the upper beds are destitute of fossils, except for a few which serve little for correlation.

The problems of correlation appear to be such as can be solved satisfactorily only by reference to the physical geography and other conditions attendant upon Neocene sedimentation, and in the light of facts gathered from districts somewhat outside the one under discussion. Doubtless marine currents during Neocene times played no small part in the distribution of the materials, and hence with the stratigraphy and thickness of the beds, and possibly also with their faunas. But it is only by recognizing the entire extent and position of the particular basin of deposition and its physical history that we gain the view requisite for the problems of correlation.

THE TEMBLOR BASIN

As shown on the maps contained in this paper the basin of deposition did not conform either in extent or position to the Great Valley of California, but, as has been pointed out in former papers,[1] it included not only a portion of the Great Valley, but also the intermontane valleys to the west. This basin was subsequently somewhat roughly described and outlined by Dr. Arnold in a paper giving broad generalizations of the environment of the Pacific Coast Tertiary faunas.[2]

From evidences that cannot be fully presented here it is believed that the Neocene basin of the California Interior was bounded on the east by the Sierra Nevada, on the south and west by the Tehachipi and Santa Lucia ranges, and on the north by a low plain, in part skirting the Sierra, but in the main occupying the northern portion of the Great Valley. The exact position of the shore-line cannot be stated, but it probably crossed the Great Valley obliquely in a northwesterly direction, receding more and more from the position of the Sierran foot-hills as it is followed northward. It is unlikely that this shore-line held its place continuously throughout the Neocene, but more probably its locus was shifted somewhat

[1] Proc. Calif. Acad. Sci., 1905, 3d ser., Geol., v. 2, pp. 157-158; Proc. Calif. Acad. Sci., 1908, 4th ser., Geol., v. 3, pp. 6-7.
[2] Jour. Geol. 1909, v. 17, pp. 520 et seq.

by the diastrophic movements of the period. As will be shown later, the conditions, if not the area, of marine deposition were greatly altered during Mid-Neocene—that is Monterey—time by wide-spread disturbances.

As stated before, the Mt. Diablo Range divides the Temblor basin somewhat centrally. Around the several island cores of this range the Neocene sediments cluster more or less continuously in concentric zones. The thickest and probably the most normal, if not the most varied, development of the Neocene is about what is locally known as the Temblor Mountains, and it is this portion of the Mt. Diablo Range that is most central to the basin here described. For these reasons, and also because the oldest beds of the Neocene, those known as the *Temblor Beds,* more accurately than any others delineate the extent and area of marine conditions, the basin may be appropriately known as the *Temblor Basin.*

About this basin, as already described, the summits of the various coast ranges lift their heads as boundary or interior monuments, well fitted to commemorate the existence of an object so important. For this basin forms in truth one of the most important unit-areas of the California Neocene, and should be treated as such in any extensive and consistent study of the deposits.

It is not believed that the various coast mountains existed as continuous ranges during the Neocene, but rather as chains of disconnected islands intermittently bounding the basin on the south and west, and also dividing it somewhat centrally in the position of the Mt. Diablo Range. About these several islands, in the wide inter-island channels, in the narrower waterways, and in the inclosed sea, the range of conditions, when affected by ocean currents, was very great, both as to sedimentation and as to the distribution of faunas; and it is only in view of these facts that correlations can be advantageously undertaken, either of deposits within this particular basin, or of deposits occurring respectively in this and neighboring basins, or of either with the standard column of the California Neocene.

Below is given a tabulated statement showing in a general way the plan suggested for the correlation of the Kern River

beds with those of the Mt. Diablo Range, and with others throughout the area of the Temblor basin.

Mt. Diablo Range	Kern River Area
Tulare Group	Not Recognized.
Etchegoin Group	Kern River Group Gray water-sands; green and brown sands, clays, etc.; sands carrying oil, oil-measures.
Santa Margarita Group Monterey Group	Unconformity, or beds not recognized.
Temblor Group	Temblor Group Zone C., clays, ashy beds, and sands with marine fossils; Zone B, gravels, clays, sands with marine fossils, diatom shales, bituminous shales, etc., Zone A, conglomerate, ashy beds, sands with marine fossils.

In his recently published paper, *The Geologic Record of California,* Dr. J. P. Smith[1] suggests without comment a tabulated correlation of the Neocene deposits occurring in and about the borders of the Temblor Basin. While the plan therein proposed is not in entire harmony with the conclusions of this paper, it fairly represents the trend of opinion, and therefore, by his courtesy, is reprinted here with slight necessary alterations, the terms in parentheses being interpolated.

THE TEMBLOR GROUP[2]

From an inspection of the fauna of Zone A described in the preceding pages, there can be but little doubt as to its identity with the lowermost beds occurring at Temblor and at other

[1] Jour. Geol., v. 18, No. 3, pp. 216-227.

[2] Dr. Arnold and others have not hesitated to apply the term *"Vaqueros"* to the Lower Miocene beds of the Mt. Diablo range which have been previously described under the name Temblor. It should be remembered, however, that the name *"Vaqueros"* has not yet any well-founded claim upon scientific or technical usage aside from its introduction into the literature of the U. S. Geological Survey. It has not yet had either a faunal or a stratigraphic description that could logically entitle it to recognition, nor has any such description been claimed for it. Its use in the literature of the U. S. Geological Survey is without reference either to logic or to the rules of precedence, and has in fact only an arbitrary basis for its support. It is hoped that its use will be discontinued.

Kern (County)			Coalinga	
(Tulare)		Tulare	Lake beds Pliocene fa with som brackish-wate	
(Base of "McKittrick Formation")		Etchegoin formation	Beds wit Pecten wa and P. coalingae	
(Santa Margarita)		Coalinga formation	Jacalitos be with Pecten owe	
			Beds wit Tamiosom gregaria, Ost titan, and Pecten estrell	
Monterey	Bituminous shales		Doubtfully ref to the Monterey	
Ocoya Creek beds	Barker's ranch beds with Agasoma barkerianum Agasoma kernianum and Pecten andersoni	Temblor	Type sectior Temblor, wi fauna like tha the Ocoya C formation	
		Vaqueros		

NEOCENE SECTIONS OF CALIFORNIA (*after J. P. Smith*)

Kern County		Coalinga		San Luis Obispo		Salinas Valley	Santa Cruz		Mt. Diablo Region	
(Tulare)	Tulare	Lake beds with Pliocene fauna with some brackish-water beds		Paso Robles	Type Section of Paso Robles, supposed to be of freshwater origin	Paso Robles: Gravels like those of the type section	Merced / Santa Clara	Marine beds of Lake Merced and freshwater beds of Santa Clara	Berkleyan	Freshwater Pliocene and Miocene of the Berkeley Hills
(Base of "McKittrick Formation")	Etchegoin formation	Beds with Pecten wattsi and P. coalingaensis		Pismo formation ?	Doubtfully referred to this horizon. It may be the equivalent of the Santa Margarita	Etchegoin: Sandstones with Scutella gibbsi and Pecten wattsi	Purisima	Marine beds of Half Moon Bay with Pecten healeyi	San Pablo	Type section on San Pablo Bay with Pecten pabloensis and Astrodapsis tumidus
(Santa Margarita)	Coalinga formation	Jacalitos beds with Pecten oweni		Santa Margarita	Typical sandstones with Ostrea titan Tamiosoma gregaria, and Pecten estrellanus	Santa Margarita: Type section of Santa Margarita with Ostrea titan Tamiosoma gregaria, Pecten estrellanus and (Pecten crassicardo)	Santa Margarita	Sandstones with Ostrea titan and Astrodapsis antiselli	Santa Margarita	Kirker's Pass beds with Santa Margarita fauna
		Beds with Tamiosoma gregaria, Ostrea titan, and Pecten estrellanus			Pecten discus bed	Pecten discus beds				Sandstones with Ostrea titan and Pecten crassicardo
Monterey: Bituminous shales		Doubtfully referred to the Monterey		Monterey	Diatomaceous shales, like the typical Monterey	Monterey: Type section of Monterey shale	Monterey	Bituminous diatomaceous shale	Monterey	Monterey shale
Ocoya Creek beds: Barker's ranch beds with Agasoma barkerianum Agasoma kernianum and Pecten andersoni	Temblor	Type section of Temblor, with fauna like that of the Ocoya Creek formation		Temblor	Sandstone with Agasoma gravidum Turritella ocoyana and Mytilus mathewsoni		Temblor	Sandstones with Agasoma gravidum Turritella ocoyana and Pecten andersoni	Contra Costa	Sandstones with Agasoma and Turritella ocoyana
	Vaqueros			Vaqueros	Massive sandstones with Turritella inezana Pecten magnolia and Mytilus mathewsoni	Vaqueros: Type section of Vaqueros, massive sandstones of the Santa Lucia Mts. with Turritella inezana	Vaqueros	Sandstones with Turritella inezana		

places in the Mt. Diablo Range and in the Temblor basin in general.

It was at first thought that this horizon might prove to be older than the typical Temblor, on account of the number of large pecten species it contained, but there is now quite abundant proof that a horizon older than the Temblor has not been recognized either here or in any part of Temblor basin, nor do the stratigraphic facts from any part of the basin furnish proof that older Neocene beds exist within it. It may be supposed that the occupation of the Temblor basin by the sea was transgressional and progressive, and that there are older beds belonging to the Neocene in the outer coast ranges; but if this is true, it has yet to be shown.

The relationship of Zone B both faunally and stratigraphically is clearly with the Miocene, and its correct reference to this period will hardly be questioned, notwithstanding the recent or modern aspect of some of the species, as already mentioned.

Not only is it to be regarded as Miocene, but the preponderance of evidence is undoubtedly in favor of its connection with the Lower Miocene. Any question which may arise as to its exact stratigraphic position is more likely to involve only a choice between the Temblor and the Monterey. But thus far in the study of the West Coast Miocene, the Monterey has not been regarded as the habitat of such species as *Agasoma gravidum, Turritella ocoyana, Cytherea mathewsoni, Dosinia whitneyi, Yoldia impressa,* and a score of other species given in the lists. Indeed, Dr. Merriam has cited all of the above-named species except the last as being characteristic of the beds *below* the Monterey shales. And none of the species of Zone B are characteristic of any Miocene horizon younger than the Monterey. And furthermore it must be added that while Zone B is rich in species some of which have often been found in the Monterey shales, the species most widely characteristic of the latter, namely, *Pecten peckhami,* has not been found at all in any part of the Kern River area.

In the same manner it may be shown that Zone C, both stratigraphically and faunally is related to the Temblor, rather than to any later division of the Neocene. All of its species are found in both Zones A and B, and while some of them

are found in the Santa Margarita, none of them are characteristic of it.

Since the entire stratigraphic group including Zones A, B, and C is quite conformable in position, and all its members are more closely related to the Temblor in faunal features than to any other horizon of the Neocene, it follows that if any part of the included strata is to be referred to a horizon other than the Temblor, it must be done upon the basis of criteria other than stratigraphical or paleontological. In the matter of thickness also there is little to warrant any subdivision of these beds.

The Temblor beds described in former papers devoted to the Mt. Diablo Range have in their type-locality an aggregate thickness of 1500 feet. Northward along the range the thickness diminishes until at Coalinga and on Cantua Creek it is hardly more than 300 feet.

In the San Emidio section it is not easy to say how much of the Miocene is to be classed as Temblor, but, judging from Whitney's description, it is not less than 1500 feet and may be more. The writer's estimate has been greater than this.

In the Kern River area the Lower Miocene beds, including Zones A and B, would have only an average thickness; and including all of the fossil-bearing beds the series aggregates only 1760 feet, a thickness quite comparable to that of the type-locality of the Temblor. Other localities are known in which the beds referable to the Temblor attain a much greater thickness than any here given. Elsewhere a statement has been given of the criteria upon which a provisional division of these beds might be attempted.

In the outer Coast Ranges of California are beds that have been described and classed under the undefined name of *"Vaqueros."* Without recognizing the sufficiency of this rambling and nondescript name, it may be said that most, if not all, of the strata that have hitherto been classed under this term are comparable stratigraphically and faunally to the Temblor. Dr. Arnold has described beds in the Santa Cruz mountains, and Dr. Fairbanks in the Coast mountains about San Luis Obispo that are referable to the Temblor. Dr. Merriam has pointed out that *Turritella hoffmani* is found

only in the Lower Miocene of the outer coast ranges, and has suggested that beds in which it occurs may be older than those of the interior valley in which *T. hoffmani* is replaced by *T. ocoyana,* abundant about the Kern River.

Thus far it remains to be shown that any such discrimination is warranted or possible. In other respects the Lower Miocene of the outer coast ranges does not differ faunally from the Temblor. Undoubtedly the Temblor group has its contemporaries among some of the Neocene river-deposits of the Sierra Nevada, but a correlation will not be attempted here with these deposits.

Monterey Shales

It is quite impossible to recognize in the outcrop in any part of the Kern River area that member of the Miocene which forms its most characteristic feature in many parts of the Coast, that is, the Monterey Shales.

In the series as described in the preceding pages, partly from the outcrop and partly from the records of deep wells, there is one portion that bears some resemblance to the Monterey, namely, that portion which is most strongly characterized by shales, some of which are organic to a considerable extent. It will be noticed that nearly every class of materials commonly found in the Monterey has been found in the upper part of the Temblor group. Some of these points have been well brought out in Mr. Carmen's description of the formations encountered in the Grace Well No. 5, quoted above. This portion of the series embraces at least 700 to 900 feet of strata, and includes and extends from Zone C downward to or below the position of Zone B, though it cannot include more than 1160 feet.

But if this collection of strata really represents the Monterey, it is hardly comparable in thickness or character to known exposures of Monterey not far away. On the western border of the valley, at Temblor, McKittrick, Midway, and Sunset, exposures of Monterey shales, almost exclusively organic, aggregate in thickness 4000 to 5000 feet. Moreover, they overlie a considerable thickness of clearly recognized

Temblor sandstones and shales which are quite comparable to those of the Kern River. It may be added also that in the outer coast ranges the thickness of the Monterey is often as great as 3000 or 4000 feet, though this thickness may not be constant.

On the other hand, as shown in previous papers, and as admitted by others, at Coalinga and vicinity the Monterey is but very little developed, and in the Mt. Diablo Range north of Jacalitos Creek it is not clearly recognizable at all, and if actually present it is in very greatly reduced volume. Nor has it been recognized at any place on the eastern border of the Temblor basin.

It may be said, then, with reference to the Temblor, and also to the Monterey, that the conditions during the early and middle Miocene were similar in the Kern River area and in the Mt. Diablo Range in the vicinity of Coalinga. In both places on the borders of the Temblor basin the Temblor deposits are fairly well developed, while the Monterey is either absent, or is present in a reduced or disguised form. There are other facts that emphasize the absence of the Monterey on the eastern and northern borders of the basin, as will be shown later.

The explanation of this interesting fact is to be found no doubt in the diastrophic record of the times. The subsidence that inaugurated the occupation of this basin by Temblor sediments continued without interruption until middle Miocene time. It then paused, and on the eastern and northern borders of the basin the shore lines remained stationary throughout the epoch of the Monterey. In these parts, therefore, sedimentation was nil, while along the western borders, in the position of the outer coast ranges, and about the southern portion of the Mt. Diablo Range, subsidence went on without cessation, and sedimentation was therefore continuous.

It is unnecessary to suppose that there was any elevation and denudation of the older Miocene during the Monterey epoch, either in the Kern River area or elsewhere, and no such disturbance seems probable. The facts appear to indicate merely an epoch of stability along the eastern and northern shore-lines of the basin, along which, therefore, the conditions

were unfavorable for the continued accumulation of any class of sediments.

But another aspect of sedimentation may well be considered in this connection, and that is the climatic conditions of the time. The Monterey epoch appears to have been one of dry, if not arid, climate. This is shown not only by the class of detrital sediments which are characteristic of this group, but also by the organic deposits, and by the class of organisms that were dominant in this basin at the time, namely *Diatomaceae,* etc.

In the various descriptions of the Monterey deposits that have been given from time to time, it will be recalled that among the materials considered as essential in its composition are diatomaceous and other organic shales, foraminiferal limestones, volcanic ash, gypsiferous clays, and disseminated bituminous matter more or less pervading the whole group. All of these materials are not only compatible with, but are characteristic of, arid conditions of climate. Furthermore, there is a generally acknowledged absence in most places of detrital or terrigenous materials. The enormous deposits built up of remains of diatoms and of foraminifera not only indicate, but they require, undisturbed and clear water, conditions that are found only under calm and clear skies. But under arid climatic conditions there would be slight denudation of land areas, and therefore but little sedimentation of terrigenous materials along a low and stationary shore line, such as bounded the Temblor basin on the east.

The Kern River Group

The correlation of the Kern River group with any occurring in the Mt. Diablo Range cannot now be made on paleontological ground, for the reason that as far as known it is without any determinative fossils. The beds of the Kern River group, however, can be followed south to the Tejon valley, and probably can be connected toward the west with similar beds extending around the south end of the Great Valley and to the Sunset and Midway oil districts. In this way the Kern River group can, perhaps, be connected with the lower part of

the Etchegoin group occurring west of Midway; but this correlation is not given as final, but only as tentative.

In lithological character the beds of the Kern River group resemble the Santa Margarita, especially in the parts containing the heavy-boulder conglomerates, and also in the gravels, and perhaps in the greenish-colored sands; but these criteria are not conclusive.

Another and stronger feature of resemblance is in the oil-measures. It is a generally recognized fact that the oil-measures of the Sunset and Midway districts are in beds of Etchegoin age, and are principally near the bottom. The well-known occurrence of oil-measures in the Kern River group gives a means of correlation that would have great weight with many, and it may well be considered to have a strong stratigraphic if not a paleontological basis, and therefore to warrant serious consideration.

The overlapping of the Kern River group upon the older groups is similar to that of the Etchegoin as exposed elsewhere. The Kern River group, however, is in the aggregate thicker than the Etchegoin, west of Midway, but on the other hand it is thinner than the Etchegoin group north of Coalinga. It is possible that the Kern River group is contemporaneous with, and equivalent to, the upper part of the Santa Margarita and a part of the Etchegoin, and represents a transgressional or progressive subsidence of the basin-floor. This view would harmonize many points not readily determined by direct proof derived from any part of the basin.

It is less satisfactory to attempt a correlation of the Kern River group with any portion of the "McKittrick Formation" for the reason that the latter is not yet sufficiently well understood. In the published description of the McKittrick formation it is made to include both marine and fresh-water beds that are readily distinguishable, and the definition is further complicated by the use of terms that are subject to dispute. The correlation of the Kern River group with any portion of the McKittrick formation must therefore await a fuller and more consistent definition. But as both the Santa Margarita and the Etchegoin beds are known to be petroliferous about McKittrick and Midway, it is likely that the equivalents of the Kern River group will be found to include portions of both.

The Quaternary Gravels

The next collection of strata following that of the Kern River group is found in the alluvial gravels and terrace-deposits of the Kern River area. These deposits have all been formed during an epoch of subsidence, if not submergence, such as is known to have taken place generally over the whole Coast region during the late Quaternary. The horizontal position of these deposits across the truncated edges of the Kern River group, and the trenching of the latter prior to the epoch of alluviation, as shown along Caliente Creek, mark an intervening epoch of land conditions and of denudation. Quite similar facts are to be seen along the base of the Mt. Diablo Range in which the Tulare deposits are involved, which have been shown to be of Pliocene age.

An attempt was made in a former paper[1] to correlate the post-Pliocene deposits about the southern end of the Great Valley, and to suggest their relation to the terracing as well as to the previous interval of land elevation and denudation.

The interpretation here given to the Quaternary terracing and older alluvial gravel-deposits in the Kern River area, is that they represent an epoch of subsidence in late Quaternary time, following the epoch of elevation which attended glacial conditions. In other words, these features of the Quaternary period are classed with those of the Champlain epoch in general.

Economic Geology

It is not the purpose of this paper to deal specially or extensively with the economic features of the district, yet in passing a few notes may be included for the benefit of those who may desire them.

The chief economic product is, of course, petroleum, though others are at least possible in the not distant future. As far as known the petroleum deposits of commercial value are confined to the Kern River group, and therein have a stratigraphic range of 300 to 600 feet, though unproductive beds of oil-sand are found both above and below. At any one point the productive sands rarely exceed 400 feet in thickness, and they are

[1] Proc. Cal. Acad. Sci., 4th Ser., v. 3, pp. 1-40.

often confined to 250 feet or less. Mechanical difficulties often make it impracticable to draw upon all of the sands capable of yielding oil, and the perforations of the casings are sometimes extended to only half the thickness of oil strata actually encountered in drilling.

Below the base of the Kern River group and, therefore, within the Temblor, oil-sands have been reported in the records of the deep wells, but none of them are known to be capable of yielding commercial quantities of oil. The oil is generally reported to be of lighter character than that from the oil-measures of the Kern River group. Thin streaks of oil-sand and stains of oil, and shales more or less colored by bituminous matter, if not with oil, outcrop in certain localities within the Temblor. Some of these are to be seen along Kern River east of the oil-field, and in the hills north of Poso Creek as, for example, near the old fuller's-earth mine. Oil-sands are reported in some old wells a quarter of a mile north of this mine, at a depth of 1300 to 1400 feet, and gas is still issuing from one of these wells in small quantity.

Gas, which is generally regarded as an indication of oil, has been encountered in nearly all of the wells, old and new, that have been drilled into the Temblor beds. Considerable quantities of gas were found in both the Grace Well No. 5, and in the deep well of the Petroleum Development Company.

Stratigraphically, the oil is not found in a single bed extending across the field, but in sandy beds more or less separated by clays and distributed through the oil-measures. The sandy beds and clays interleave, often forming an alternating series throughout the measures. As a rule, in the developed portion of the field the sands are thicker in the eastern part of the field and become thinner toward the west, and the clays are thicker on the western border and become thin and scattered toward the east. In like manner the sands are thicker toward the south, and clays increase in volume northward.

There is considerable lack of uniformity in the well-records; but this is probably due more to faulty records than to irregularities in the beds themselves. Both sands and clay-beds are believed by some to be lenticular in section, and this is sometimes given as the cause of troubles met with in controlling the underground water. But if a lenticular condition has really

been observed in any case, it is likely to have been found along certain directions, and belongs primarily to the sands rather than to the clays, since it would owe its origin to the sorting action of currents during deposition. However, the idea of this condition comes solely from a study of the well-records, and the faulty data furnished by some of these should not be forgotten. If a well-record fails to record a particular bed of clay, it does not prove its absence, but possibly only a failure to detect it.

The structure of the beds is almost that of a simple monocline, but when studied in detail the beds undulate somewhat, forming slight anticlines and synclines striking N. W. to S. E.

The ultimate areal extent of the field has not been proved by actual developments, though the limits may be definitely known toward the northeast, if not also toward the southwest.

Thus far water has proved to be more troublesome on the southwestern border of the field; and this is partly on account of the thinner clay beds in this direction, and the greater difficulty met with in shutting it out from the wells, or in confining it to certain limits by means of these clays.

The gravity of the oil varies from 10.4° B. to 17.0°, though a large percentage of the production is between 14.5° and 16° B. Still lighter oil comes from strata below the oil measures of the Kern River group.

Water-sands, which are the source of much trouble, are found both above and below the productive beds—some within the oil-measures, though in some cases water has been let into the oil-measures by accident or by faulty drilling. It is usually possible to shut out the upper water, and when the horizon of the lower water-sands is once learned, drilling may be stopped above it. There are usually sufficient clays suitably situated for the control of the underground water if the conditions are correctly known beforehand.

The question as to the origin of petroleum is one much debated; but in California there is overwhelming evidence in favor of an organic origin, and the facts point to certain low organisms of both marine and fresh-water habitat. In the Tertiary formations of California, *Diatomaceae* are extremely abundant, and beds that are largely composed of their remains

abound in all parts of the Neocene series, excepting possibly the latest. In the Mt. Diablo Range diatomaceous and other organic shales often make up a large percentage aggregate of the Monterey and later groups, and they occur also in the Etchegoin group, included by Ralph Arnold in the so-called "McKittrick series."

The opinion has been unequivocally expressed[1] that in the Coalinga field the real source of the petroleum is in the Eocene shales underlying the Neocene, and that migration of the petroleum upward through the strata has brought it into its present repositories in the Neocene oil measures. That petroleum, in some parts of the Mt. Diablo Range and elsewhere, has originated in the Eocene cannot be denied, and it is also now found there in many places. But to conclude that all or any of the Neocene oil-measures have derived their supplies from the Eocene is illogical and unnecessary. The Neocene beds themselves contain the same organisms in even greater abundance than does the Eocene, and this is particularly true in the Mt. Diablo range. And there is no reason to suppose that the oil found in the Neocene measures has not originated in the Neocene strata themselves.

The view here expressed is that the oil found in any Neocene group has more probably originated in that group, and that migration would be far easier along the planes of bedding and lamination than at right angles to the same. That thick beds of clay and shale often restrain oil, water, and gas, is quite well demonstrated in California, and even within the Temblor basin the upward transverse migration of these substances under enormous pressure has been successfully resisted by certain impervious beds, possibly clays.

Naturally in the sedimentation of any basin the sandy detritus usually remains near shore, and the finer materials are carried away to other localities to be deposited. Also if *Diatomaceae* and other delicate organisms form any appreciable deposits they will more probably be formed off shore. In subsequent regional deformations of the strata, the organic deposits are apt to be left occupying the position of synclinal depressions, bounded by the sandy shore line deposits left lying

[1] U. S. Geol. Surv. Bull. No. 357, p. 73.

in positions inclined toward the interior of the basin. If such organic deposits give rise to any supply of petroleum or other liquid or gaseous substances, these may be forced to migrate laterally along the bedding-planes of the strata, and into the sandy strata of the border, far more readily than they could be forced upward through the clays and shales and into overlying beds.

And, if deposits of petroleum are subsequently found in sandy shore-deposits, we may expect to find not far away in the same beds the source and origin of it. Along the Kern River the conditions are all that could be required to support the view that lateral migration has been the means by which accumulation has taken place, and the same may be said of all the other producing or non-producing fields in the Temblor basin. The extent to which water, oil, and gas may migrate laterally along bedding-planes in the progress of geologic periods is, of course, very great; but the fact that it is retained at all in the rocks, even under enormous pressure, is very good proof that it cannot migrate in a vertical direction, transverse to the bedding-planes.

Thus far but little effort has been made to discover or develop water for irrigation or for other uses in the Neocene beds about the Kern River, except for field use within the Kern River district. It is worth while to note the fact, however, that water of economic value has been found in certain strata of both the Temblor and Kern River groups. In neither case has the water been found free from objectionable substances, though in each it is usable for all ordinary purposes in which relatively pure water is needed.

One of the most important attempts to develop water for economic use has been made by the Associated Oil Company in the western part of the district. On Sec. 5, T. 29 S., R. 28 E., several wells have been devoted to, or drilled for, the production of water, and these wells are supplying large volumes of water at a cost that brings it within economic limits for irrigating some kinds of crops.

None of these wells are more than 400 feet in depth, and most of the water is within 375 feet of the surface, and above the oil-measures.

Diastrophic Record

The Neocene diastrophic record in California has been more or less studied by all of the writers who have attempted the problems of correlation. Naturally there is not entire harmony in the conclusions of all, but all agree as to the main facts.

Dr. Fairbanks summarized much of the information current at the time of his writing in a paper entitled *Oscillations of the California Coast,*[1] though considerable additional information has since been developed. The conclusions as to the diastrophic record reached in the present study of the Temblor basin may be more concisely presented graphically in the accompanying diagram.

While some of the oscillations portrayed may be more or less local, they nevertheless show a tendency toward physical change that may be wide-spread, though not universal or uniform, within a given region. Furthermore, it may be stated that the oscillations here delineated do not include all that have recently been proposed by certain writers ambitious to cause a stir.

It is believed that the conclusions of this paper, however, are in harmony with those of Dr. Smith set forth in the paper before referred to and quoted. But it is not designed to carry the subject farther at the present time.

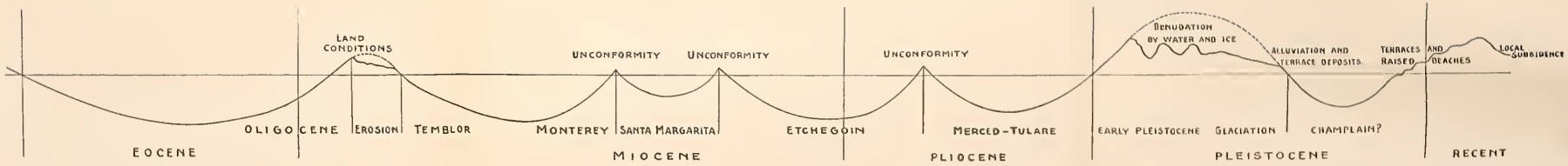
Conclusions

The more important conclusions which may be drawn from the statements of the preceding pages are briefly summarized in the following paragraphs.

The Neocene deposits of the Kern River area show a surprising lack of development when contrasted with contemporaneous deposits in the Mt. Diablo Range.

The comparatively small aggregate thickness of the series is partly explained by the fact that they do not contain all of the members of the generally accepted column of the California Neocene, or even all that have been recognized in the Mt. Diablo Range, which admittedly holds all that are most characteristic.

[1] Am. Geol., v. 20, 1897, pp. 213-245.



DIASTROPHIC RECORD DURING THE NEOCENE IN THE TEMBLOR BASIN AND MT. DIABLO RANGE, CALIFORNIA.

The Monterey group is either absent from the column, or if present, cannot be separated from the Temblor.

An epoch of disturbance following the deposition of the Temblor group is indicated by the faulting of the beds, which has left some of them at a considerable altitude and quite severed from the main area of the foot-hills.

The unconformity of the Kern River group upon the Temblor is emphatically shown by an overlapping of the later group, although there is no clear evidence of an intervening epoch of erosion.

The absence from the Kern River area of any recognizable Monterey deposits, and presumably their absence from the whole eastern border of the Temblor basin, perhaps means a recessional movement of the sea, and therefore at least a slight upward movement of the land along its eastern and northern shores, and along portions of the Mt. Diablo Range.

The greatest depression of the land-surface during the Neocene seems to have been during the Temblor epoch, and immediately following this was the Monterey epoch of relative elevation.

The sequence of events during the early and middle Miocene, as shown in this area, conforms generally to that shown in the contemporaneous deposits about Coalinga and northward.

The local contrasts in the thickness of the Temblor deposits in and about the Temblor basin, and especially in their volcanic and detrital matter, suggest that land-denudation on the continental side was relatively slight, while volcanic activity was prevalent during this epoch.

The general absence of Monterey deposits, and the other evidences of elevation, taken in connection with the prevailingly organic character of these beds where they do occur, may be interpreted as indicating equable or arid climatic conditions; and the small aggregate thickness of Miocene strata on the landward side of the basin harmonizes with this view and may mean that such conditions prevailed in some measure throughout the Miocene.

The Kern River group is correlated only tentatively with the oil-yielding formations of western Kern County, and such correlation is based chiefly on the data of the oil-measures themselves.

The absence of the Tulare group from the Kern River area is probably due partly to its removal by erosion and partly to its being mantled over by terrace-deposits and other Quaternary gravels.

An epoch of land-conditions and therefore of elevation preceded the formation of at least some of the alluvial deposits, and it may have been during this epoch that the Tulare beds suffered most from denudation.

The fresh-water or brackish-water facies of the Temblor beds is local; and, taken in connection with the local embayment in the shore line of this epoch, affords evidence of estuarine conditions along the lower portion of the Caliente canyon, and indicates the entrance at this place of a considerable stream, derived doubtless from the contiguous portions of the Great Basin.

Logs of Deep Wells

Log of Well No. 52, Kern Trading and Oil Company, Sec. 3, T. 29 S., R. 28 E., Kern River District.

From	To	Thickness	Formation
Surface	30 feet	30 feet	Sand and clay
30 feet	58 "	28 "	Boulders
58 "	260 "	202 "	Sand and clay
260 "	290 "	30 "	Light oil-sand
290 "	300 "	10 "	Clay
300 "	330 "	30 "	Rich oil-sand
330 "	355 "	25 "	Clay
355 "	440 "	85 "	Good oil-sand
440 "	455 "	15 "	Clay
455 "	465 "	10 "	Good oil-sand
465 "	485 "	20 "	Hard sand
485 "	500 "	15 "	Good oil-sand
500 "	510 "	10 "	Clay
510 "	550 "	40 "	Good oil-sand
550 "	560 "	10 "	Clay
560 "	610 "	50 "	Good oil-sand
610 "	615 "	5 "	Clay
615 "	630 "	15 "	Oil-sand
630 "	640 "	10 "	Clay
640 "	665 "	25 "	Rich oil-sand and boulders
665 "	670 "	5 "	Clay
670 "	715 "	45 "	Oil-sand and gas
715 "	725 "	10 "	Clay
725 "	740 "	15 "	Good oil-sand
740 "	750 "	10 "	Clay
750 "	775 "	25 "	Clay
750 "	775 "	25 "	Oil-sand
775 "	789 "	14 "	Hard sand
789 "	805 "	16 "	Hard sand (4 feet below casing)

Log of Well No. 5, Grace Oil Company, Sec. 8, T. 29 S., R. 28 E., Kern River District.

The upper part of this log is similar to others in this field and is not specially interesting.

From	To	Thickness	Formation
429 feet	761 feet	232 feet	Oil-sands, etc.
761 "	1061 "	300 "	Oil-sands
1061 "	1080 "	19 "	.....
1080 "	1100 "	20 "	Sandy shale
1100 "	1285 "	185 "	Sands, with water
1285 "	1305 "	20 "	Oil-sands
1305 "	1332 "	27 "	Clay and shale
1332 "	1352 "	20 "	Sandstone
1352 "	1388 "	36 "	Tough clay
1388 "	1390 "	2 "	Black shell
1390 "	1420 "	30 "	Coarse sand
1420 "	1442 "	22 "	Blue clay
1442 "	1507 "	65 "	Coarse sand (oil?)
1507 "	1535 "	28 "	Clay and sand
1535 "	1555 "	20 "	Coarse sand (oil?)
1555 "	1561 "	6 "	Blue clay
1561 "	1634 "	73 "	Sand (oil?)
1634 "	1666 "	32 "	Sand and clay
1666 "	1708 "	42 "	Sticky shale
1708 "	1715 "	7 "	Sand (asphaltum)
1715 "	1786 "	71 "	Shale, with some sand
1786 "	1798 "	12 "	Shale and sand
1798 "	1823 "	25 "	Clay shale and sand, with gas
1823 "	1835 "	12 "	Sand
1835 "	1846 "	11 "	Hard clay shale
1846 "	1871 "	25 "	Sandstone
1871 "	1875 "	4 "	Tough clay
1875 "	1921 "	46 "	Sand, with oil
1921 "	1937 "	16 "	Tough clay
1937 "	1971 "	34 "	Sand
1971 "	1998 "	27 "	Sticky clay
1998 "	2004 "	6 "	Coarse sand
2004 "	2040 "	36 "	Sandy shale
2040 "	2047 "	7 "	Sand, with oil
2047 "	2083 "	36 "	Clay shale
2083 "	2087 "	4 "	Sand, with oil and water
2087 "	2118 "	31 "	Clay shale, with shell
2118 "	2129 "	11 "	Water-sand
2129 "	2150 "	21 "	Soft shale
2150 "	2175 "	25 "	Hard shale
2175 "	2194 "	19 "	Sand (firm)
2194 "	2195 "	1 "	Sandstone
2195 "	2206 "	11 "	Dark clay shale
2206 "	2209 "	3 "	Sand, with fossils
2209 "	2217 "	8 "	Dark clay shale
2217 "	2242 "	25 "	Clay and sand alternating
2242 "	2260 "	18 "	Coarse gravel
2260 "	2591 "	331 "	Shale, with hard shells
2591 "	2701 "	110 "	Sand shale, with gas and oil
2701 "	2712 "	11 "	Sand
2712 "	2758 "	46 "	Shale

November 1, 1911.

Log of Well No. 5, Grace Oil Co.—Cont'd.

From	To	Thickness	Formation
2758 feet	2763 feet	5 feet	Hard shell
2763 "	2775 "	12 "	Sand
2775 "	2814 "	39 "	Shale, with white specks
2814 "	2837 "	23 "	Sand, with gas
2837 "	3148 "	311 "	Shale, with gas
3148 "	3166 "	18 "	Fine white sand
3166 "	....	....	Strong salt water

Log of Well No. 43, Kern Trading and Oil Company, Sec. 3, T. 29 S., R. 28 E., Kern River District.

From	To	Thickness	Formation
Surface	230 feet	230 feet	Sand and clay
230 feet	425 "	195 "	Light oil-sand—Water at 400 feet
425 "	452 "	27 "	Clay
452 "	475 "	23 "	Oil-sand and gas
475 "	485 "	10 "	Clay
485 "	530 "	45 "	Rich oil-sand
530 "	542 "	12 "	Clay
542 "	580 "	38 "	Rich oil-sand
580 "	600 "	20 "	Dry sand—Some gas
600 "	648 "	48 "	Oil-sand
648 "	650 "	2 "	Clay
650 "	690 "	40 "	Oil-sand
690 "	710 "	20 "	Clay
710 "	750 "	40 "	Oil-sand
750 "	753 "	3 "	Clay
753 "	760 "	7 "	Oil-sand
760 "	765 "	5 "	Clay
765 "	810 "	45 "	Light oil-sand
810 "	820 "	10 "	Rich oil-sand
820 "	823 "	3 "	Dry sand
823 "	830 "	7 "	Rich oil-sand
830 "	833 "	3 "	Clay
833 "	835 "	2 "	Dry sand—Bottom

Log of Well No. 31 ("Rasmussen"), Petroleum Development Company, Sec. 4, T. 29 S., R. 28 E., Kern River District.

From	To	Thickness	Formation
Surface	34 feet	34 feet	Surface formation
34 feet	85 "	51 "	Sand gravel and blue clay
85 "	262 "	177 "	Sand shale and blue clay
262 "	330 "	68 "	Oil-sand
330 "	405 "	75 "	Blue clay and hard sand
405 "	425 "	20 "	Oil-sand
425 "	450 "	25 "	Clay and sand
450 "	500 "	50 "	Oil-sand
500 "	650 "	150 "	Oil-sand and blue clay
650 "	695 "	45 "	Oil-sand
695 "	718 "	23 "	Blue clay and oil-sand

Water shut off at 255 feet.
Gas blew out top of rig at 437 feet.

Log of Well No. 51, Kern Trading and Oil Company, Sec. 3, T. 29 S., R. 28 E., Kern River District.

From	To	Thickness	Formation
Surface	30 feet	30 feet	Sand and clay
30 "	58 "	28 "	Boulders
58 "	260 "	202 "	Sand and clay
260 "	290 "	30 "	Light oil-sand
290 "	300 "	10 "	Clay
300 "	330 "	30 "	Rich oil-sand
330 "	335 "	5 "	Clay
335 "	440 "	105 "	Good oil-sand
440 "	455 "	15 "	Clay
455 "	465 "	10 "	Good oil-sand
465 "	485 "	20 "	Hard sand
485 "	500 "	15 "	Good oil-sand
500 "	510 "	10 "	Clay
510 "	550 "	40 "	Good oil-sand
550 "	560 "	10 "	Clay
560 "	610 "	50 "	Good oil-sand
610 "	615 "	5 "	Clay
615 "	630 "	15 "	Oil-sand
630 "	640 "	10 "	Clay
640 "	665 "	25 "	Rich oil-sand and boulders
665 "	670 "	5 "	Clay
670 "	715 "	45 "	Oil-sand and gas
715 "	725 "	10 "	Clay
725 "	740 "	15 "	Good oil-sand
740 "	750 "	10 "	Clay
750 "	775 "	25 "	Oil-sand
775 "	789 "	14 "	Hard sand

Log of Well No. 2, Petroleum Development Company, Sec. 24, T. 28 S., R. 27 E., Kern River District.

From	To	Thickness	Formation
Surface	460 feet	460 feet	Sand and clay
460 feet	570 "	110 "	Blue water-sand
570 "	590 "	20 "	Blue clay
590 "	610 "	20 "	Blue clay
610 "	615 "	5 "	Oil-sand
615 "	640 "	25 "	Blue clay and water-sand
640 "	1040 "	400 "	Water-sand and blue clay
1040 "	1051 "	11 "	Blue clay
1051 "	1087 "	36 "	Water-sand
1087 "	1135 "	48 "	Water-sand and clay
1135 "	1190 "	55 "	Heaving water-sand
1190 "	1435 "	245 "	Sand and clay
1435 "	1445 "	10 "	Coarse water-sand
1445 "	1465 "	20 "	Blue clay and sand
1465 "	1490 "	25 "	Water-sand
1490 "	1500 "	10 "	Hard standstone
1500 "	1725 "	225 "	Water-sand and blue clay
1725 "	1731 "	6 "	Sand, showing oil
1731 "	1790 "	59 "	Water-sand and blue clay
1790 "	1792 "	2 "	Coarse sand, showing oil and gas
1792 "	1845 "	53 "	Sand and clay, showing oil

Log of Well No. 2, Petroleum Development Co.—Cont'd.

From	To	Thickness	Formation
1845 feet	1890 feet	45 feet	Sticky blue clay
1890 "	1900 "	10 "	Blue clay, showing oil
1900 "	1930 "	30 "	Water-sand, showing oil
1930 "	2000 "	70 "	Sand and clay, showing oil
2000 "	2105 "	105 "	Sand and clay
2105 "	2130 "	25 "	Hard white sand
2130 "	2240 "	110 "	Hard brown shale
2240 "	2245 "	5 "	Fine white sand, showing some oil
2245 "	2270 "	25 "	Fine white sand

This well was abandoned.

Log of Well No. 28 ("Rasmussen"), Petroleum Development Company, Sec. 4, T. 29 S., R. 28 E., Kern River District.

From	To	Thickness	Formation
Surface	30 feet	30 feet	Sand and boulders
30 feet	285 "	255 "	Clay and sand
285 "	330 "	45 "	Blue clay and oil-sand
330 "	335 "	5 "	Oil-sand
335 "	430 "	95 "	Oil-sand and clay
430 "	470 "	40 "	Oil-sand
470 "	490 "	20 "	Oil-sand and blue clay
490 "	540 "	50 "	Blue clay
540 "	800 "	260 "	Blue clay and oil-sand
800 "	820 "	20 "	Oil-sand
820 "	905 "	85 "	Oil-sand and blue clay
905 "	1350 "	445 "	Sandy clay
1350 "	1360 "	10 "	Blue clay
1360 "	1397 "	37 "	Sandy blue clay
1397 "	1450 "	53 "	Blue clay
1450 "	1455 "	5 "	Blue clay and sand
1455 "	1461 "	6 "	White sand
1461 "	1472 "	11 "	White sand and clay
1472 "	1625 "	53 "	Sandy clay
1625 "	1652 "	27 "	Brown sandy clay
1652 "	2405 "	753 "	Brown shale
2405 "	2480 "	75 "	Sandy shale
2480 "	2566 "	86 "	Brown shale
2566 "	2580 "	14 "	Brown shale and sand
2580 "	2585 "	5 "	Sand, with fossil shells and salt water
2585 "	2612 "	27 "	Sand and brown shale
2612 "	2690 "	78 "	Hard brown shale
2690 "	2694 "	4 "	Hard sandy shale
2694 "	2805 "	111 "	Hard sand
2805 "	3000 "	195 "	Gray shale
3000 "	3050 "	50 "	Sand
3050 "	3240 "	190 "	Gray shale
3240 "	3255 "	15 "	Gray shale and brown sand
3255 "	3370 "	115 "	Blue shale
3370 "	4295 "	925 "	Gray shale
4295 "	4580 "	285 "	Brown shale
4580 "	4650 "	70 "	Sandy shale
4650 "	4660 "	10 "	Sand and some oil
4660 "	5010 "	350 "	Gray shale, etc.

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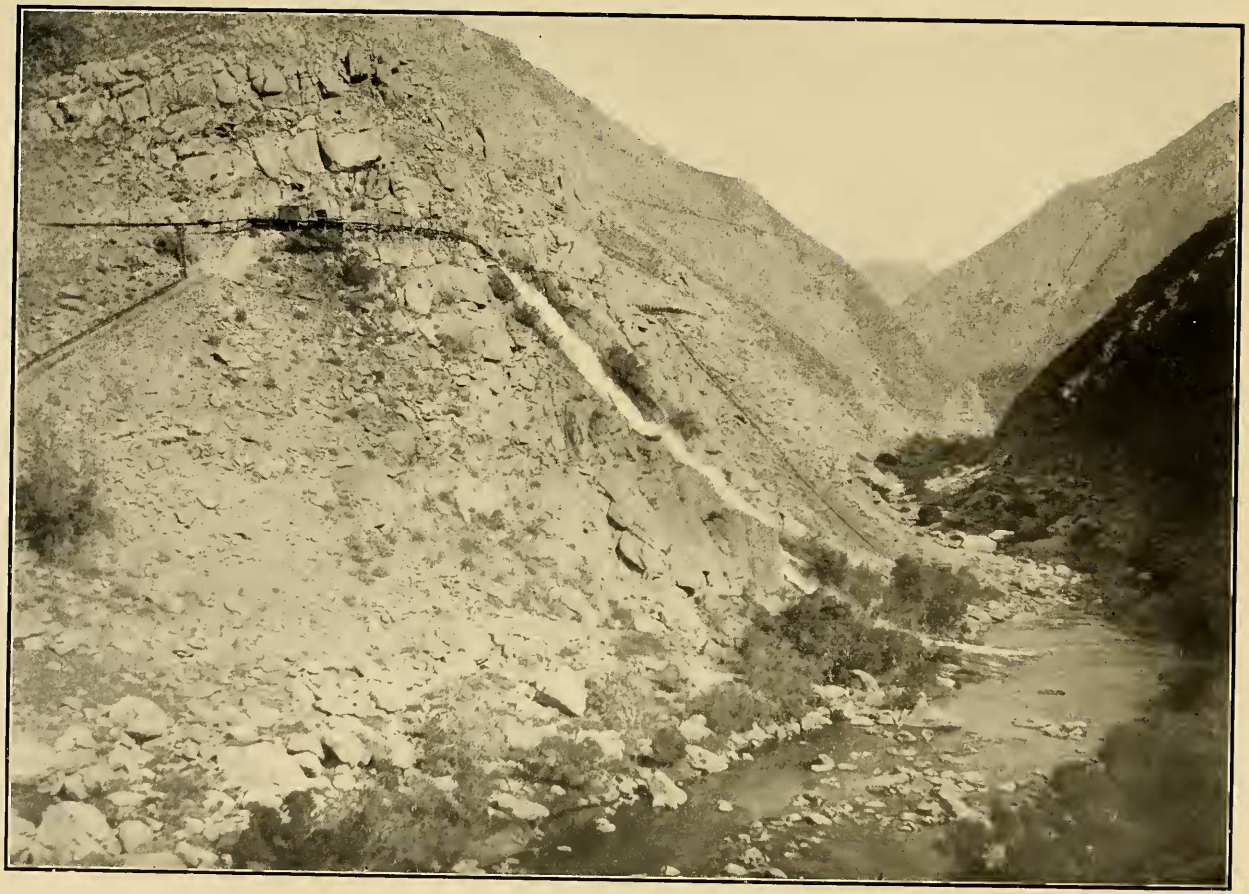
CALIFORNIA ACADEMY OF SCIENCES,
February 25, 1911.

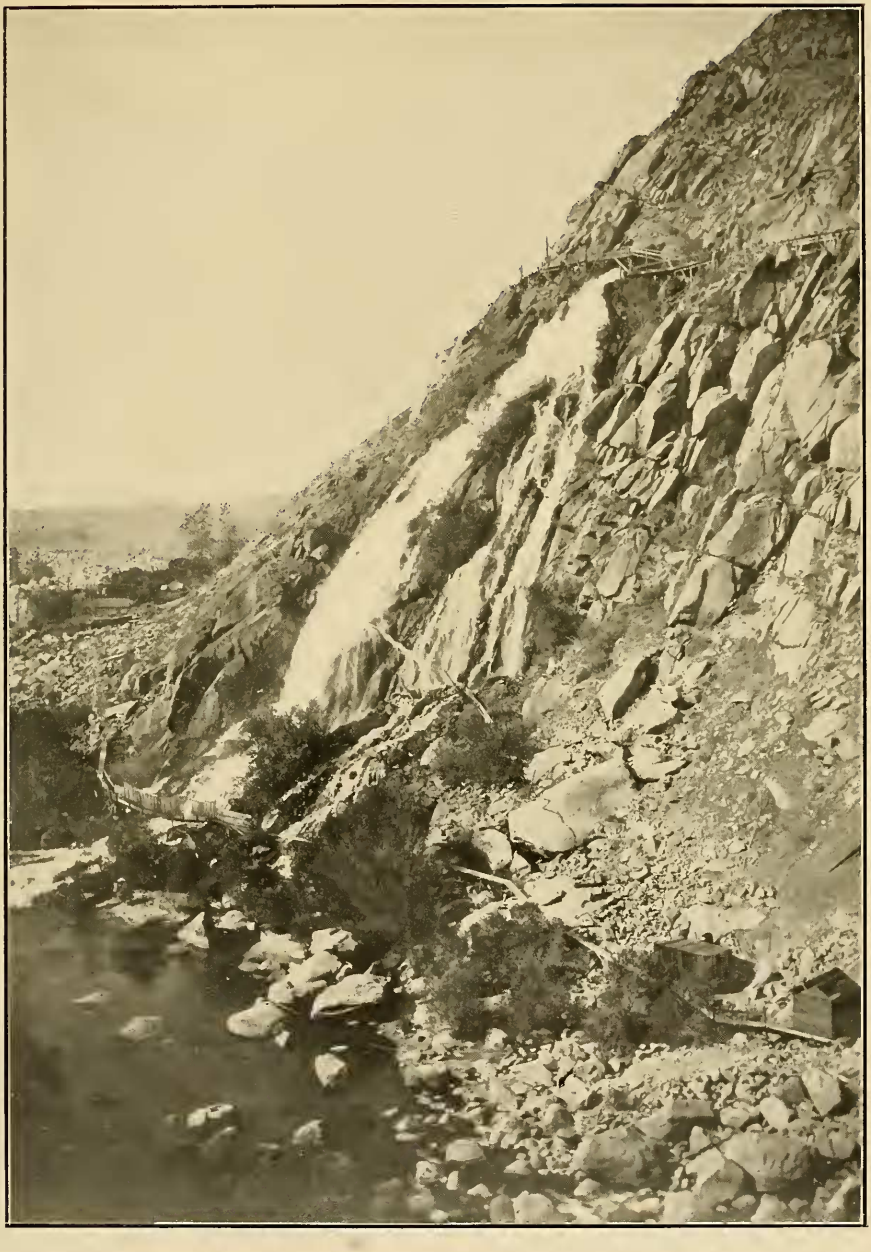
EXPLANATION OF PLATE IV

View showing defile of the Kern River, looking east at point of debouchure from the granite. The slight shoulders on each side of canyon in middle distance correspond approximately to top of lacustrine delta-terraces.



EXPLANATION OF PLATE V.

View at mouth of the Kern River defile, looking west. Old flood-plain shown on left of the river forming a wide terrace 40 feet above the present level of the stream. Granitic rocks on the extreme left.



EXPLANATION OF PLATE VI

View near mouth of the Kern River defile, looking north. Boulder-strewn flood-plain in foreground; old flood-plain terraces in middle distance strewn with river gravels; steep granite scarp in background along line of faulting.

EXPLANATION OF PLATE VII

View on the Kern River looking east. Recent flood-plain of river shown on the right and left in middle distance; older flood-plain terraces shown in background, cut into Tertiary (Neocene) formations; granitic ridge in extreme background.